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COMMENTS SUBMITTED TO THE
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ON ITS PROPOSED LISTING OF PAGEL'S PIT ON
THE SUPERFUND NATIONAL PRIORITIES LIST
(Proposed October 15, 1984)

December 14, 1984

TABLE OF CONTENTS

APPENDICES

A. Photographs Showing Construction of the Asphalt Liner and Cationic Sealer at the Winnebago Reclamation Service, Inc. Solid Waste Disposal Site (Pagel's Pit).

B. Solid Waste Disposal Site Permit issued by IEPA for "Pagel's Landfill" Facility.

C. Affidavit of Charles J. Howard, President of Winnebago Reclamation Service, Inc., with Attachments.

D. Letter Report from Warzyn Engineering, Inc., April 28, 1980, and IEPA Memorandum of Aug. 14, 1981, Documenting Acme Solvents as Probable Source of Well Contamination East of Pagel's.

E. Illinois EPA Monitoring Data Sheet Showing Presence of Arsenic and Other Substances at Acme Solvents Site (March 9, 1982).

F. Article: Cline and Viste, "Migration and Degradation Patterns of Volatile Organic Compounds" (1984).

G. Article: Wood, Lang & Pagan, "Anaerobic Transformation, Transport and Removal of Volatile Chlorinated Organics in Groundwater" (1981).

H. Articles: "Lining of Waste Impoundment and Disposal Facilities", U.S.E.P.A. (1983) (excerpts); Haxo, et al., "Liner Materials Exposed to Municipal Solid Waste Leachate" (1981).

I. Articles: Lubold, "Battling Groundwater Pollution", Asphalt, July/Oct. 1975; "Hot Mix Keeps Landfills Sanitary", Paving Forum, Fall/1977; "Asphalt for Environmental Liners" (brochure from National Asphalt Pavement Association (1984)).

J. Hazardous Waste Quantity Calculations Based on Materials Not Delivered to Pagel's; Summary of Alternate HRS Scores.

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Introduction

The following comments are submitted on behalf of Winnebago Reclamation Service, Inc. in response to EPA's Notice of Proposed Rulemaking published in the Federal Register on October 15, 1984, 49 Fed. Reg. 40320. Pagel's Pit (Pagel's) is a land disposal site located approximately 5 miles south of Rockford, Illinois, in a rural unincorporated area of Winnebago County. The facility is licensed by the Illinois EPA for solid waste disposal. EPA proposes to add Pagel's to the National Priorities List (NPL) issued under the authority of Section 105(8) of the Comprehensive Environmental Response, Compensation and Liability Act of 1980. Winnebago Reclamation Service, Inc. is the owner and operator of this facility. These comments are directed to EPA's proposal to include it on the NPL.

The NPL is supposed to contain those sites "that appear to present a significant risk to public health or the environment". 49 Fed. Reg. 40320 (Oct. 15, 1984). EPA concluded that Pagel's is such a site based on a projected score under the Hazard Ranking System of 42.47. This score is higher than the 31.98 assigned to the nearby upgradient Acme Solvents site, a solvents reclaiming and disposal facility using unlined lagoons, which appeared on both the Interim Priority List and the first formal National Priorities List. Since its inception in 1972, Pagel's has been permitted as a solid waste disposal facility by the Illinois EPA

(IEPA) and has operated in compliance with that permit. It was designed and built with a state-of-the-art liner and leachate collection system. It has never been charged with any violation of any federal, state, or local environmental protection law or regulation. We have been advised that of all of the NPL sites listed or proposed in Illinois, this is the only one not recommended by the State for listing.

Yet under EPA's scoring, Pagel's is considered a greater public health hazard than the Acme site, which is 12 years older than Pagel's, never had a permit, and was closed for failure to comply with environmental requirements. In addition, Acme disposed of primarily hazardous materials, and it did so by dumping uncontainerized liquid solvents and sludges with high concentrations of heavy metals into unlined lagoons with direct access to groundwater. EPA's ranking of Pagel's is premised upon the theory that Pagel's is leaking and that a plume of groundwater contamination is flowing from the facility into the aquifer beneath it where it is interacting with the plume originating at Acme. (<u>E.C. Jordan Final Remedial Investigation Study for the Acme Solvents Superfund Site</u>, Vol. I, Sept. 1984, Figure 32.)[1] Thus the inference of an "observed release" from Pagel's as a separate source has been

[1] This study is cited hereinafter as "E.C. Jordan Final". A draft of this report dated July, 1984, was cited and relied upon by EPA in its HRS evaluation of Pagel's, which was dated June 11, 1984, and hence inexplicably purports to have been completed prior to the existence of the report on which it relied. The final report became available in September. We did not receive a copy of that final report until late November and have not yet received a final copy of the Appendix to the report, although we have requested a copy.

drawn even though the compounds in question are known to be spreading from Acme, merely because Pagel's is in the vicinity.

That theory is not supported by the administrative record. First, there is no empirical evidence that Pagel's liner has leaked. Second, even in its current state, the record indicates that a more plausible theory is that Acme is the sole source of the observed contamination in the area. The available data (including hydrogeologic, groundwater quality, and leachate quality data) indicate that Acme Solvents is the major contributor, and possibly the only contributor, to groundwater contamination in the area. These data indicate that strong downward groundwater gradients beneath Acme allow for downward movement of contaminants from that site within the groundwater system. Relative densities of chlorinated hydrocarbons compared to water may also account for this downward movement of the contaminants where the contaminants are high enough in concentration to remain undissolved or partially dissolved. As groundwater moves westward from Acme towards Pagel's, the vertical groundwater gradients change to predominantly lateral flow, and then flow upwards towards Pagel's in response to local hydrogeologic conditions. In particular, the bedrock turns downward in the vicinity of Pagel's, and the groundwater at that point flows into sandy soils as it approaches Pagel's.

The limited data from monitoring wells between the two sites is consistent with this analysis. Shallow wells between the two sites are generally uncontaminated, while deeper domestic wells in the same area are contaminated, reflecting the presence of the contaminated plume. In addition, biodegradation of volatile organic contaminants within the groundwater system from beneath Acme, discussed more fully below, provides a reasonable explanation for the transformation of primary contaminants from Acme to degradation products which appear in the vicinity of Pagel's. While the presence of different chemicals may give the initial appearance of indicating distinct plumes, the biodegradation relationships between the two sets of chemicals, discussed below, is consistent with the theory of long-term movement of a single plume originating from beneath the Acme site, coupled with slow biodegradation as the contaminants move westward towards Pagel's.

Winnebago Reclamation Service has hired the firm of Warzyn Engineering, Inc. to conduct additional groundwater sampling and analysis in the area between the Acme and Pagel's locations and in the immediate vicinity of Pagel's. This study is expected to be completed by mid-February, 1985, and should provide additional important data concerning groundwater flow and plume analysis. We will submit the results of that study to EPA as soon as it is completed, and we ask EPA not to include Pagel's on any NPL at least until the results of that study have been carefully reviewed and analyzed. Meanwhile, recognizing that Pagel's is in the vicinity of a 24-year-old known pollution source for some or all of the contaminants of concern, absent evidence of a plume emanating from Pagel's, an HRS score based upon an observed release is unwarranted.

Re-ranking Pagel's on the basis of route characteristics and containment criteria, rather than observed release, results in a

Hazard Ranking Score of, at best 0, and at worst 10.53. Either score is well below the current 28.50 cut-off and is consistent with current conditions at the site. Pagel's should therefore be taken off the proposed NPL update.

I. DESCRIPTION OF PAGEL'S PIT SITE, ACME SITE, AND PROPOSED NPL LISTING OF PAGEL'S.

A. The Pagel's Pit Site.

Prior to its development as a sanitary landfill, the area comprising what is now Pagel's Pit contained a sand and gravel pit and a dolomite quarry. It was converted into a landfill area in response to Winnebago County's need for an environmentally sound solid waste disposal area. From its inception, the site was conceived and operated as a non-hazardous waste disposal area. Contrary to the statements on EPA's HRS cover sheet, no landfill operations were conducted at the site prior to 1972.

Pagel's was constructed with the full knowledge and close cooperation of the Illinois EPA and the active encouragement of the local community. The landfill consists of a large basin, much like a large bathtub. (Appendix A, Photographs 1 and 2).[1] The basin is lined with a high-integrity asphalt liner system which was constructed in the following manner. The subbase of the landfill was leveled and covered with compacted road stone. This material was then primed and covered with two inches of asphaltic

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[1] Referenced photographs showing the various states of construction are included in Appendix A.

concrete, creating a permeability rating of 1×10^{-7} cm/sec. (Appendix A, Photographs 3, 4, 5, and 6). This asphalt liner was covered in turn with a cationic coal tar sealer to further reduce permeability to approximately 1×10^{-9}. (Appendix A, Photographs 7, 8, 9, and 10.) This is a well recognized, widely used, and highly effective type of liner, as discussed below at pp. 27-28. The asphaltic concrete provides a stable base to which the cationic coal tar sealer binds permanently. Bound to the asphaltic concrete base in this manner, the sealer cannot move or crack.

A leachate collection system was also installed to remove any liquid which was generated by or found its way into the landfill from the surface of the liner. The cationic coal tar sealer was covered with six to eight inches of sand. A series of six-inch leachate collection pipes was then installed, and covered with an additional two to three inches of sand and tires for protection. (Appendix A, Photographs 12 and 13). The leachate which was so collected was initially drained into leachate tanks, which were later replaced by ponds located in the middle of the landfill within the liner, and 40 to 60 feet above it. Pumps placed at regular intervals in manholes on the floor of the liner remove leachate to these ponds. The leachate which flows into the leachate ponds through this system is trucked off-site for disposal to the Sanitary District of Rockford.

The State of Illinois issued Permit #1972-24 authorizing operation of the site as a solid waste disposal site to Pagel's Pit on April 7, 1972. A copy of that permit is attached hereto as Appendix B. The site opened on July 17, 1972, after the construction and installation of the asphaltic cement with coal tar sealer liner.

Pagel's has been operated in compliance with the letter and spirit of this permit and Illinois law throughout its history. From the outset, the operators of the facility have kept in close communication with the Illinois EPA to make sure that no wastes were accepted at the site which were hazardous or which would damage the facility.[1] Whenever the facility operators had a question concerning the acceptability of certain wastes, a supplemental permit for special wastes was requested from the Illinois EPA as required by Illinois law.[1] The requests were accompanied by a description of the chemical composition of the material in question. A number of such permits were issued which were never used, apparently due to the generator's decision, after inquiry, to take the wastes elsewhere.[1] The operators of the facility in each case advised the Illinois EPA that it would not accept any wastes which IEPA regarded as inappropriate for disposal there. No "special wastes", defined under Illinois law to include hazardous or industrial wastes, were accepted without a supplemental permit from IEPA authorizing acceptance. Throughout its

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1/ See Appendix C hereto, Affidavit of Charles J. Howard, President, Winnebago Reclamation Service, Inc., ¶ 2 and Exhibit 1 (hereinafter "Howard Aff.").

1/ A number of such permits are contained in the EPA list of references supporting the Pagel's HRS ranking as Ref. No. 3.

1/ Howard Aff., ¶ 4 and Exhibit 2.

operation, Pagel's has maintained complete records of materials accepted under such permits.

In 1980, several domestic wells to the east of the Pagel's site (towards Acme) were found to contain high concentrations of volatile organic chemicals. A field investigation by IEPA attributed the cause of this pollution to the Acme Solvents site rather than to Pagel's.[4] Winnebago Reclamation nonetheless undertook the task of providing the affected residents with bottled drinking water as a "good neighbor" gesture because no one else came forward to do so.

In short, this is not an abandoned hazardous waste disposal site. It is a carefully managed and properly licensed solid waste disposal facility. It was established in response to requests by the community, including the City of Rockford, for just such a facility, and it serves a number of valuable and necessary functions for the community. It has an enviable record of environmental compliance and close cooperation with state and local authorities. There is no direct evidence of any environmental contamination emanating from this facility.

However, this facility has the bad luck to be located downgradient from the nearby Acme Solvents site, a heavily contaminated and leaking Superfund site. It is to that site that we next turn.

4/ This is documented in a sampling and analysis report by Warzyn Engineering dated April 28, 1980, and an IEPA memorandum dated August 14, 1981. Copies of both are attached hereto as Appendix D.

B. The Acme Solvents Site.

The Acme Solvents site is located to the east of Pagel's Pit, across Lindenwood Road. (E.C. Jordan Final, Fig. 2). It is a twenty-acre site which was operated as a disposal facility from 1960 until 1973. Spent solvents and sludges from the company's solvent distillation units in Rockford were dumped into seven open, unlined lagoons on the site. These materials contained high concentrations of heavy metals such as arsenic, chromium, lead, cadmium, and copper, and volatile organic chemicals such as methyl ethyl ketone, toluene, zylene, trichloroethylene, and trichloroethane. Between 10,000 and 15,000 drums were stored in various locations around the site. (Remedial Action Master Plan, Acme Solvent Reclaiming Site, Weston, February 1983; EPA list of references supporting the Pagel's HRS, Item 7 at 2-1 and 2-7, hereinafter cited as RAMP ___; E.C. Jordan Final at 9). During the height of its operation, Acme was disposing of between 450 and 600 gallons of waste per day. (E.C. Jordan Final at 9).

This site, by contrast with Pagel's, never had an IEPA permit. Indeed, IEPA's first contact with the site was an inspection in February of 1972 in response to a report filed by an area game biologist. On September 25, 1982, Acme was formally charged with a number of environmental violations at a hearing before the Illinois Pollution Control Board. As a result of the hearing, Acme agreed to begin remedial actions to clean up the site including (1) drainage and off-site disposal of materials in the lagoons; (2) removal of all 55-gallon drums to an EPA-approved landfill;

and (3) filling the storage lagoons with clean fill. (RAMP at 2-1, 2-2; E.C. Jordan Final at 2). Instead, Acme backfilled the lagoons without removing the contents and crushed and buried the majority of drums on-site. (Id.). This uncontrolled waste disposal resulted in the formation of a contaminated groundwater plume moving to the west of the site and contamination of domestic water supply wells along Lindenwood Road and the accumulation of approximately 27,000 cubic yards of contaminated soils. (Ecology and Environment, Inc., Field Investigation of Uncontrolled Hazardous Waste Site - Extent of Groundwater Contamination - Acme Solvents Pagel's Pit Area near Morristown, Il., Task Report to EPA, March 1983, at 40-42, EPA list of references supporting the Pagel's HRS, Item 1, hereinafter cited as "E&E at ___"; see also Appendix D hereto).

As a result of the discovery in 1980 of contaminated domestic wells, EPA undertook a series of investigations to determine the extent of the groundwater contamination at the Acme site. A geologic study showed Acme perched on an area of relatively shallow and exposed bedrock overlain by gravelly sand. The bedrock was found to be deeply weathered and, where exposed, extensively fractured. Subsurface conditions were similar, "competent zones were found to overlie weathered and highly fractured zones". (E.C. Jordan Final at 31). The bedrock plunges steeply to the northwest beneath Pagel's Pit. The area beneath Pagel's on a horizontal level with the bedrock beneath Acme is filled with clayey and granular deposits. (Id.).

Groundwater flow in the area was determined to be east to west (from Acme towards Pagel's), with some localized north and south currents flowing away from the Acme site resulting from groundwater mounding caused by disposal activities and recharge from a nearby creek. (E.C. Jordan Final at 40). The shallow aquifers in this area are hydrologically connected to the deeper highly productive sandstone aquifers providing the water supply for large industrial and municipal wells in the Rockford vicinity. (RAMP at 2-5).

The contaminated private water supply wells are located between Acme and Pagel's along Lindenwood Road, downgradient from Acme. In 1982, Ecology and Environment, Inc., an EPA contractor, installed 17 monitoring wells in and around the Acme site. (E&E at 13). In 1983, E.C. Jordan, another EPA engineering contractor, installed an additional 7 monitoring wells and 8 piezometers. (E.C. Jordan Final at 13). None of these monitoring wells was deep enough to tap the bedrock between the Acme and Pagel's sites, although the contaminated domestic wells located in that area were drilled into the bedrock, and numerous references to strong downward movement of groundwater appear in both studies.[1]

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[1] For example, the E&E Report notes "Soils in the upland areas east of Pagel's Pit are well to excessively well drained, thus promoting downward migration of contamination" (E&E at 40). The E.C. Jordan Report notes deep well B-6D adjacent to the Acme site "consistently revealed a substantially lower level, which indicated a downward gradient on the order of 0.1 to 0.4 ft/ft during the period of monitoring. . . . These observations suggest the presence of a deep zone that is considerably more pervious than the overlying dolomite. This <u>pervious zone may act as a drain to the overlying aquifer</u>." (E.C. Jordan Final at 41) (emphasis added). Winnebago Reclamation has been informally advised by representatives of E.C. Jordan that Jordan recommended the installation of deeper monitoring wells between the two sites but these were not included in their remedial investigation.

The Acme site was listed on the interim National Priorities List of 160 sites issued in 1981 and on the first National Priorities List of approximately 400 sites. 48 Fed. Reg. 40658 (September 8, 1983). Acme received an HRS score of 31.98. Its groundwater pathway score was 54.63 based upon an observed release of 1,1,2,2 tetrachloroethane, 1,1,1 trichloroethane, and trans 1,2 dichloroethane. These included some of the very contaminants detected in the residential wells between Acme and Pagel's during an IEPA site investigation on July 29, 1981. (E&E at 4-5).

C. EPA's Proposal To List Pagel's Pit.

The E&E Report identified both Pagel's Pit and Acme Solvents as potential sources of the groundwater contamination of the aquifer. (E&E at 3, 40). Pagel's was implicated based upon record review of the types of waste disposed of, or for which Pagel's had obtained supplemental permits, and upon arsenic concentrations discovered in Well B-15, located on the opposite side of the unpaved private roadway along the northern boundary of Pagel's. (E&E at 29; E.C. Jordan Final, Fig. 4). No arsenic was detected in any other well during this round of sampling. However, arsenic has been found in the soils at the Acme site and in groundwater samples from Well G-103 on the Acme site, establishing its presence in the groundwater there as well. (See Appendix E hereto).

E&E identified Acme as the primary source of the volatile organic contamination since it found the highest concentrations of these chemicals in Well B-4, immediately adjacent to Acme. E&E noted that an obvious mechanism of release of these substances was through rainfall percolating "through the porous overburden on the Acme Solvent property, through the buried wastes, through into the fractured and weathered bedrock, and on into the groundwater". (E&E at 28).

The report noted without explanation that Pagel's was "apparently" the source of the arsenic. (E&E at 42). It also noted, without explanation, that Pagel's could be a source of additional organic chemicals. It recommended installation of additional wells or piezometers to determine whether mounding was actually occurring under the Pagel's site, as would be expected if the site were leaking. (E&E at 44). No such mounding has been detected under Pagel's by any study conducted to date.

Based upon data from the E&E report, and the arsenic result in particular, EPA prepared a Hazard Ranking Score for Pagel's in December of 1983, which was 40.70. The score was based upon a high value for the groundwater migration pathway, which in turn was premised upon the assumption of an "observed release" of arsenic. The EPA HRS scoring document attributes an arsenic release to Pagel's based upon supplemental permit #74-162 which authorized disposal of forty 55-gallon drums of arsenic-bearing chemical waste. Total waste quantity was estimated at 119,970 gallons or 1,983.4 drums based upon other supplemental permits.[1]

On June 11, 1984, a final HRS was prepared for Pagel's. This score was 42.47. It again was premised upon an assumed "observed

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1/ These permits, as listed in worksheets accompanying the EPA draft score, included Nos. 75-33; 75-34; 75-35; 75-36; 75-37; 75-80; 75-81; 74-72 and 74-107.

release" of arsenic to groundwater, but also listed observed releases of cadmium and bis (2-ethyl hexyl) phthalate. This HRS advanced a new rationale for attribution of these three chemicals to an observed release from Pagel's. E.C. Jordan used data collected in 1980 by the Sanitary District of Rockford, as well as subsequent sampling of its own, to identify these chemicals in leachate at the site inside the liner.[1] E.C. Jordan had concluded, based on that fact and additional monitoring data, that a separate groundwater contamination plume originates at Pagel's. Waste characteristics were rated at 24 based upon an estimate of 2,737 drums identified in supplemental permits, which the scorer noted "would be lowered by quantities not actually delivered". (6/11/84 HRS backup worksheet, p. 4). Finally, Pagel's received a targets score of 39 based upon use of the aquifer as a drinking water source with the nearest well within 0.1 mile and estimating 430 individual residences served within a 3-mile radius. (Id.). This targets score was 10 points higher than the targets score for Acme, located directly across the road. (Acme HRS sheet, July 22, 1982).

Believing this score to be unwarranted by the available evidence, Winnebago Reclamation Service asked Warzyn to conduct an

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[1] The 1980 sample of the leachate showed a cadmium concentration of 0.044 mg/l and an arsenic concentration of .038 mg/l. (EPA list of references supporting the Pagel's HRS, item 2). E.C. Jordan's 1984 sample of the leachate was not re-tested for the presence of arsenic and cadmium; it was tested for the presence of volatile organic compounds. Concentrations of bis (2-ethyl hexyl) phthalate were found to be 28 ug/liter. (E.C. Jordan Draft, Appendix F, Table 4).

additional groundwater investigation, as noted above. The purpose of this investigation is to: (1) determine whether there is any evidence of contamination emanating from Pagel's; (2) provide additional information on contaminants at depth between the Pagel's Pit site and the Acme Solvents site; and (3) evaluate potential impacts from the eastern margin of the Pagel's Pit site. In essence, the study is designed to plug existing gaps in the data base and provide a more solid basis for defining groundwater movement and the source of contamination in the Acme and Pagel's area.

The program will consist of installing nine additional wells, four of which will be instrumented as deep piezometers to monitor the conditions at depth within the aquifer, between the two sites. The five additional water table wells are situated around the eastern portion of the landfill (the portion closest to Acme Solvents) to detect any groundwater mounding and/or leachate emanating from the landfill. All newly installed monitoring wells, in addition to selected previously installed wells, will be sampled on two occasions to obtain additional groundwater quality information. Groundwater levels will be taken from all previously existing and newly installed wells on four occasions to develop a larger data base with regard to groundwater flow conditions. Results of this study are expected in February of 1985, at which time they will be supplied to EPA. At the present time, the available evidence, as discussed below, indicates that Pagel's is not a separate source of the observed contamination and that it should therefore not be included on the National Priorities List.

II. THE HRS SCORE OF 42.47 IS UNWARRANTED BECAUSE THERE IS NO OBSERVED RELEASE OF HAZARDOUS MATERIAL WHICH CAN BE ATTRIBUTED TO THIS SITE.

The statutory purpose of the Hazard Ranking System under Superfund Section 105(8) is to produce a list of "the highest priority facilities" based on actual or threatened releases of hazardous substances and the resulting "danger to public health or welfare or the environment". No such danger is posed by Pagel's.

The high HRS score which EPA proposed for Pagel's in its worksheet of June 11, 1984, is based upon what EPA has characterized as an observed release of arsenic and cadmium in one well and bis (2-ethyl hexyl) phthalate in three wells. The reasons for attributing this release to Pagel's are (1) similarity to chemicals found in leachate samples taken from inside the liner at Pagel's, and (2) the conclusion in the E.C. Jordan report on the Acme Solvents site that Pagel's is a separate source of groundwater contamination.[10]

The general assumption supporting the score is therefore that Pagel's is leaking. This assumption is based upon a series of inferences in the E.C. Jordan report which are not supported by that study or underlying data. As set forth below, these conclusions are inconsistent with evidence based on the leachate and

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[10] A different reason for attribution was given in the earlier draft HRS of December 8, 1983. In that document, attribution was based upon a supplemental permit issued to Pagel's for disposal of forty 55-gallon drums of arsenic-bearing waste. That reason for attribution was dropped after Winnebago Reclamation confirmed for EPA that this permit was never used.

groundwater samples themselves, the groundwater contaminant transport model predictions contained in the E.C. Jordan report, current knowledge about actual groundwater movement in the area, and the continuing lack of evidence that any groundwater mound is forming underneath Pagel's.

A. Analytical Data Fail To Show A Relationship Between The Pagel's Pit Leachate And Contaminated Groundwater Beneath The Site.

If the leachate from Pagel's were a separate source of the groundwater contamination observed in the area, the primary constituents of that leachate - i.e., its specific chemical fingerprints - would be observed in the samples taken from wells around the site. However, the available analytical data do not show any of the major chemical constituents of the leachate in the groundwater beneath and/or downgradient of the site, as would be expected if the leachate from the Pagel's facility were leaking through the liner.

The compounds detected in the highest concentrations in the leachate inside the facility were 2,4 dimethylphenol, phenol, xylenes, isophorone and toluene. (E.C. Jordan Draft, Appendix F, Table 4; EPA list of references supporting Pagel's HRS score item 15). None of these compounds was detected in any of the monitoring wells or water supply wells, with the exception of toluene. Toluene was only detected in Well B-4, the well immediately adjacent to the Acme Solvents site, and the well which also contained the highest overall amount of volatile organic chemicals. This well is located upgradient from Pagel's, so that Pagel's would not be a likely source. Furthermore, the administrative record specifically identifies toluene as a chemical which was disposed of at Acme, and which chemically would be expected to leach into the groundwater at that site. (E.C. Jordan Final at 56).

In addition, if the Pagel's leachate were a separate source of groundwater contamination, concentrations present in the leachate inside the facility would be higher than those found in the groundwater. The record shows the contrary is true. Those compounds detected in the internal leachate samples which are also found in monitoring wells around the site were generally found in lesser concentrations in the leachate than in the groundwater. Trans 1,2 dichloroethene and 1,1 dichloroethane were detected in the leachate at 15 ug/l and 7 ug/l respectively. (E.C. Jordan Draft, Appendix F, Table 4). In each of the monitoring wells in which these compounds were detected, except for Well B-15, the compounds were found in greater concentrations in the well than in the leachate inside the liner.[11/]

With respect to the data for Well B-15, if the arsenic and cadmium observed in that well were coming from Pagel's Pit, similar concentrations would be expected to be observed in the downgradient wells located to the west of Pagel's, G-104, P-1, and MW-106. This is because groundwater contamination occurs in plumes,

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11/ Benezene and ethylbenzene were cited as additional leachate specific indicators detected around Pagel's Pit landfill. These compounds as well were only detected in one well (B-15) and present in higher concentrations there than in the leachate. (E.C. Jordan Draft, Appendix F, Table 3 and Table 4).

not in spots. E.C. Jordan made no attempt to determine the existence of such a plume by sampling these wells for arsenic and cadmium. Jordan simply assumed the existence of such a plume. The pending sampling by Warzyn will include this sampling which Jordan failed to do. The record, on the other hand, does show that arsenic and cadmium are present in the soil at Acme (E.C. Jordan Draft, Appendix F, Table 2), and groundwater tests at Acme well sites have also demonstrated the presence of arsenic in groundwater at Acme. (See Illinois EPA Sampling report, attached hereto as Appendix E).

The only remaining chemical attributed to Pagel's on the HRS observed release score sheet is bis (2-ethyl hexyl) phthalate. One of the downgradient wells, MW-106, does show concentrations of this chemical. However, the record shows that bis (2-ethyl hexyl) phthalate is present in concentrations of several thousand mg/kg on the Acme property. (E.C. Jordan Final at 56). In any event, the value of these concentrations as an indicator of the presence of hazardous wastes is questionable since "phthalates are commonly encountered in environmental sampling and analysis because of their ability to leach from a wide variety of plastic materials, and to opportunities for analytical interference caused by that leaching". (E.C. Jordan Final at 63, citing US EPA 1975, 1982).

To summarize, E.C. Jordan assumed a plume without even doing the sampling at the wells which are relevant to such a theory. Jordan ignored the fact that all three chemicals of concern are present at Acme and have migrated in the direction of Pagel's.

B. Available Groundwater Analytical Data Do Not Require The Inference That Pagel's Is Creating A Separate Plume Of Contamination; Instead They Strongly Suggest That Acme Solvents Is The Source Of The Contamination.

The E.C. Jordan report interprets analytical data from groundwater samples as indicating that the plume from the Acme Solvents site is chemically distinct from the plume of contaminants found in the vicinity of Pagel's Pit. (E.C. Jordan Final at 72-77). In fact, the data support the theory of a single plume of contaminants originating at Acme, based on the nature of the chemicals and the biodegradation relationships between them.

First, the rationale underlying the E.C. Jordan conclusion is not entirely clear since the report contains contradictory statements on the similarity of the groundwater beneath the two sites.[12] However, assuming that the rationale is based upon the fact that the chemical makeup of the groundwater around the two facilities is somewhat different, the E.C. Jordan conclusion is questionable because the difference in chemical composition could also result from the biodegradation of contaminants released by the Acme Solvents plume. In view of the length of time these contaminants have been in the ground (nearly 25 years) and the chemical relationships between them, such biodegradation is the more likely explanation of the observed differences.

12/ For example, on page 73, the final report states both that "chemicals present in the Pagel's Pit and Acme Site wells are similar" and that "the concentration profile data (on the plume chemistry) strongly suggest that Pagel's Pit and the Acme site are acting as separate sources of groundwater contamination".

The existence of a single source plume is supported by the nature of the substances present and by groundwater chemistry transformations known to occur. The key chemical difference observed by the report between the two areas is the amount of trans 1,2 dichloroethylene,[11] which appears to be greater under the Pagel's site than it is under the Acme site. Trans 1,2 dichloroethylene is commonly confused with cis 1,2 dichloroethylene, because most laboratories do not distinguish between these two isomers. (Appendix F, Cline and Viste, Migration and Degradation Patterns of Volatile Organic Compounds (1984), at 2-3). Cis 1,2 dichloroethylene is a biodegradation product of trichloroethylene. In fact, such degradation is the primary source of dichloroethylene, which is not produced commercially. (Appendix G, Wood, Lang & Pagan, Anaerobic Transformation, Transport and Removal of Volatile Chlorinated Organics in Groundwater (1981), at 2). Trichloroethylene is found in large quantities at the Acme site. (RAMP at 2-7; E.C. Jordan Final at Tables 12, 16). It appears very likely that most of the trans 1,2 dichloroethylene in the groundwater is actually cis 1,2 dichloroethylene. (Cline and Viste, supra, at 2-3).

The difference in the plume chemistry as reflected by the difference in the relative amount of trichloroethylene and trans

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[11] General patterns aside, however, it should be noted that the highest concentration of trans 1,2 dichloroethylene was found in Well B-4 on the Acme site indicating without question the presence of this chemical in groundwater beneath Acme. (E.C. Jordan Draft, Appendix F, Table 3).

1,2 dichloroethylene could be due to transport of the contaminants away from the source. (Id. at 5-10). E.C. Jordan has correctly recognized that Pagel's Pit is situated downgradient of the Acme Solvents site based upon measurements of groundwater levels in monitoring wells around the sites. (E.C. Jordan Draft, Figures 19, 20 and 21). Since Pagel's Pit is downgradient of Acme, contaminants released by Acme during its early active dumping phase some 20 to 25 years ago have been in the groundwater system much longer than those immediately adjacent to the Acme site. The time-dependent process of biodegradation could account for the increased proportion of 1,2 dichloroethylene observed in groundwater beneath Pagel's. (Cline and Viste, supra).

Similarly, 1,1 dichloroethane is a biodegradation product of 1,1,1 trichloroethane. Both compounds were found in groundwater at and downgradient of Acme Solvents. The proportion of 1,1 dichloroethane to 1,1,1 trichloroethane seems to increase with distance away from the Acme site, a pattern similar to that noted for trichloroethylene and its transformation product, trans 1,2 dichloroethylene. (Cline and Viste, supra, at 2, 5-10).

C. The E.C. Jordan Computer Transport Model Supports The Theory Of A Single Plume Of Contamination Originating At Acme.

The text of the final E.C. Jordan report states that "it is very unlikely that a single plume emanating from the Acme site is responsible" for the actual contaminant distribution depicted in Figure 28 of the report based on groundwater sampling results. (E.C. Jordan Final at 89-90, emphasis supplied). The text of the draft E.C. Jordan report, which EPA relied on to support its HRS score for Pagel's states, however, that "on the basis of modeling results, it is <u>very likely</u> that a single plume emanating from the Acme site is responsible for the contaminant distribution shown in Figure 28". (E.C. Jordan Draft at 111, emphasis supplied). Both the draft and final reports conclude, however, that separate plumes from Pagel's and Acme are a more "plausible scenario for the development of a bimodal plume" apparently because there is no independent evidence that the observed plume between the two sites is continuous. (E.C. Jordan Final at 90; E.C. Jordan Draft at 111). Despite the change in the textual conclusions in the final report, the model as a factual matter and as described in draft Appendix H, the only currently available form of that appendix, can as easily be interpreted to support the single plume theory.

Simulations were performed with numerous variations of aquifer conditions. Of the nine multivariable simulations, <u>six</u> modeled a plume extending from Acme under the Pagel's Pit landfill. (E.C. Jordan Draft, Appendix H, Figures 6, 9, 10, 11, 13, and 14). All simulations had a generally continuous plume, with portions of the plume either under or headed toward the southeast portion of the landfill. The actual plume configuration as shown in Figure 28 shows that the highest level of contaminants around the landfill were detected in the southeast corner of the site. This evidences the model's general credibility since the model predicts greater concentrations in that area in simulations showing one plume of contamination originating at Acme.

The results of these simulations provide strong support for a single source plume in view of the fact that the model is somewhat flawed by its failure to take into account vertical migration of contaminants. The lack of deep monitoring points between Acme and Pagel's makes it difficult to ascertain the true character of the contaminant plume between the two sites for purposes of comparison to the model. In particular, groundwater sampling data from the private wells between the two sites do not appear to have been entered into the model. As described above, the hydrogeological investigation now under way will include bedrock monitoring within this area and provide additional information relevant to an accurate assessment of the modeling results.

D. <u>Theoretical Attribution Of A Separate Groundwater Plume To Pagel's Is Predicated On Incomplete Information On Groundwater Behavior In The Immediate Area.</u>

The 1983 E&E report described the Pagel's Pit-Acme area as one characterized by strong vertical movement of groundwater, possibly affected by increased permeability of the underlying geologic material. (E&E at 21-23, 41). E.C. Jordan does not directly acknowledge in its Remedial Investigation Report that information on vertical movement is incomplete. However, the author of the draft appendix entitled "Groundwater Flow Solute Transport Model", upon which E.C. Jordan relies for several of its conclusions, clearly so states. Under "recommendations", the author notes that "Use of the model has indicated that, for a more complete understanding of hydrogeology of the site and the fate of site related contaminants more detailed information regarding the vertical movement of groundwater at the site needs to be obtained." (E.C. Jordan Draft, Appendix H at 19).

Throughout the preceding comments, we have set forth the evidence and rationale for the single plume theory of contamination of the entire area originating at the Acme site. The limited groundwater monitoring data presently available are consistent with a single plume of contamination moving from Acme down into the bedrock and westward until it reaches the more permeable materials beneath Pagel's where it discharges upward. (E.C. Jordan Final, Figs. 17 and 21). This movement is consistent with the fact that the bedrock plunges steeply beneath Pagel's, allowing the groundwater to migrate easily into the more permeable material. (_Id_.). This theory is currently supported by the following pieces of information.

As noted, at Wells MW-105, B-6S, and B-6D, steep downward gradients are associated with the groundwater mound thought to exist under the Acme site. In E.C. Jordan's view, "These observations (of vertical gradients at well nest B-6) suggest the presence of a zone at depth that is considerably more pervious than the overlying dolomite." (E.C. Jordan Final at 41). Regardless of permeability changes with depth, the layers and fractures of the dolomite bedrock serve as the primary migration route for contaminant transport away from the Acme site. As described in this analysis, the dissolved contaminants will flow with the groundwater system in response to local hydrogeologic conditions. In this case, the contaminants would move through the dolomite bedrock discharging upward into the more permeable sand and gravel soils under Pagel's where the dolomite surface drops very abruptly to the west.

The groundwater investigations conducted to date have apparently missed this contaminant pathway because there are no monitoring wells which sample at depth in the dolomite aquifer between Pagel's Pit and the Acme site. However, the three private water supply wells (E, F, and G) found to be contaminated with volatile organic chemicals in 1981 are in this general area. Since these wells are believed to be drilled to deeper intervals in the dolomite than the shallow monitoring wells around them the observed chemical contamination, which matches the Acme plume for at least some substances (e.g., trichloroethane), could reflect the presence of a plume in the deeper bedrock area. Monitoring Well MW-104, which is located south of the Acme site and is the second deepest well installed around the site, also showed a relatively high volatile organic chemical concentration, 52 ppb, and could therefore be viewed as reflecting the same Acme plume.

Finally, the samples from the deepest well in the piezometer series at the west end of Pagel's (Wells P3, P4, and P5) also supports the bedrock contamination theory. The highest total volatile organic chemical content there was found at the deepest well (P5), the only one sampling groundwater in the dolomite. Completion of the hydrogeological study which is now in progress will provide further evidence relevant to this interpretation of groundwater flow in the area.

E. There Is No Evidence Supporting The Development Of A Groundwater Mound Beneath Pagel's Pit.

As further support for its theory that Pagel's is leaking contaminants, the E.C. Jordan report infers that "there appears to be a tendency for development of a groundwater mound in the immediate vicinity of Pagel's Pit as evidenced by P3, P4 and P5". (E.C. Jordan Final at 44). This is pure speculation, unsupported by any factual evidence. Any mounding occurring in the vicinity of those wells may be attributed to intense periodic recharge in the vicinity of the wells and not due to leakage from the landfill. The wells are located at the base of a closed basin adjacent to the landfill and after heavy precipitation recharge of collected water occurs. Observed vertical gradient at these wells is not always downward in the shallow groundwater, as would be expected if mounding due to leakage from the landfill was occurring.

F. Other Facts Contradict The Observed Release Theory.

There is no objective reason to support the hypothesis that Pagel's is leaking. As described above, the site was constructed with an excellent liner. Although the asphalt is not intended to serve as the "seal" or liner at Pagel's, EPA itself has recognized that a two-inch hydraulic asphalt concrete liner alone can be compacted to have a permeability coefficient less than 1×10^{-7} cm/sec. (Appendix H hereto, Landreth, Lining of Waste Impoundment and Disposal Facilities, SW-870, U.S. Environmental Protection

Agency, Cincinnati, OH (March 1983) at 66). The cationic seal, a type of bituminous seal applied to the liner, reduces this permeability factor to less than 1 x 10^{-9} cm/sec by closing the pores in the asphalt concrete. (Id. at 101; Haxo, H.E., R.M. White, P.D. Haxo, and M.A. Fong, Liner Materials Exposed to Municipal Solid Waste Leachate - Final Report (U.S. Environmental Protection Agency, Cincinnati, OH, Contract No. 68-03-2134, 1982) (excerpts included in Appendix H hereto)). Liners which consist of only asphalt or only a cationic coal tar sealer or both are approved by state and federal agencies for use in solid waste management facilities. (Lubold, Battling Groundwater Pollution, Asphalt, July-Oct. 1975; Hot Mix Keeps Landfills Sanitary, Paving Forum, Fall 1977; Asphalt for Environmental Liners (brochure from Nat'l Asphalt Pavement Assoc. (1984)); copies of all attached as Appendix I hereto).

Moreover, the force which would initiate leakage in a well-drained area such as this is the head created by the presence of leachate on top of the liner. The leachate collection system at Pagel's and the 8-inch sand cover over the liner, however, results in a continuous pumping of the leachate away from the liner.

In summary, we believe we have presented sufficient information to allow consideration of an alternative interpretation of the available groundwater chemistry and hydrogeological data. In particular, this information suggests that Acme Solvents may be the sole source of the groundwater contamination problem in the area. The alternative interpretation relies on biodegradation of organics to explain similarities and differences of groundwater chemistry below the Acme and Pagel's sites. The local hydrogeology helps explain the impacts noted to date. The E.C. Jordan report does not conclusively link leachate quality from Pagel's with downgradient monitoring well impacts. Groundwater modeling does not consider all of the variables or available data to accurately predict in-field conditions or impacts, but in its current state, can also be used to generally support the premise that Acme may be the sole source of contamination. An additional hydrogeological investigation is currently being conducted to determine the validity of the alternative interpretation.

III. AN HRS SCORE FOR PAGEL'S BASED UPON ROUTE CHARACTERISTICS AND CONTAINMENT CRITERIA APPLIED TO ANY OF THE MATERIALS OBSERVED IN THE LEACHATE RESULTS IN A BEST CASE SCORE OF 0 AND A WORST CASE SCORE OF 10.53.

As arsenic does appear in leachate samples from Pagel's, even though in concentrations well below the primary drinking water standard set by EPA under the Safe Drinking Water Act for arsenic of .050 mg/l,[14] the facility could be re-ranked based upon a potential or threatened release of this material. Line 1 on the HRS groundwater worksheet would then be zero, requiring analysis of the four other factors listed on the sheet. These factors are route characteristics, containment, waste characteristics, and targets. A series of alternative scores has been prepared, using different assumptions. These are described below and set forth in the chart attached hereto as Appendix J.

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[14] 40 C.F.R. § 141.11(b) (1984).

Route characteristics and containment were not scored for Pagel's on the original worksheet, as these two categories are deleted when an observed release occurs. 40 C.F.R. Part 300, App. A, § 3.1. We have computed scores for both to reach an HRS figure based upon threatened release.

Route characteristics for Pagel's should receive a score of 9, calculated as follows:

- Depth to Aquifer of Concern was assigned a value of 2, based upon E.C. Jordan Final, Fig. 16, which shows a distance of slightly more than 20 feet between the refuse and the water table. 40 C.F.R. Part 300, App. A, § 3.2 assigns such a distance a value of 2.

- Net precipitation was assigned a value of 2, based upon E.C. Jordan Final, Table 5, showing a net precipitation of 13.05 inches for this area. 40 C.F.R. Part 300, App. A, § 3.2 assigns a value of 2 to this amount of precipitation.

- Permeability of unsaturated zone was also assigned a value of 2, based upon the E.C. Jordan Final, Table 2, rating of between 10^{-4} and 10^{-5} cm/sec, and the HRS value of 2 for such material set out in Table 2 of 40 C.F.R. Part 300, App. A, § 3.2.

- Physical state was assigned a value of 3, based upon the leachate as the substance of concern and upon the fact that some of the material disposed of at the site initially arrived in liquid form, although at the time of disposal it was mixed with solid waste. 40 C.F.R. Part 300, App. A, § 3.2.

These figures together give a route score of 9.

Containment was assigned a score of 0 as best case and 2 as worst case. The Hazard Ranking System Users Manual authorizes a zero score on this factor for a landfill meeting the following description: "Essentially non-permeable liner, liner compatible with waste, and adequate leachate collection system." 40 C.F.R. Part 300, App. A, § 3.3, Table 3. Of the possible descriptions listed in Table 3, Pagel's most closely resembles this description since, as discussed above, the combination of the asphalt liner and cationic sealer render it "essentially non-permeable". An alternate score, however, has been computed assigning containment a score of 2 based upon a worst-case assumption (which we have no reason to believe is the case) that the site has a "moderately permeable compatible liner".

The waste characteristics score has been recomputed based upon the analysis of available evidence. The toxicity and persistence factor of waste characteristics was scored the same as on EPA's sheet - 18 - based upon arsenic as the waste of concern. The hazardous waste quantity, however, was reduced from 6 to 2 based upon the EPA record and facts set forth in the Howard Affidavit, ¶ 4, attached hereto as Appendix C. These documents show that Pagel's did not in fact accept or receive 2,611 of the 2,737 drums of waste counted by EPA in its assessment, thus reducing the score on this factor from 6 to 2.[15] Those drums

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[15] The final score sheet for Pagel's HRS merely references Item 3 on the supporting worksheet references, which is a summary of supplemental permits, as the source of the 2,737 drums of waste constituting hazardous waste quantity for Pagel's. The draft HRS, however, identifies a number of specific permits which were counted, including permit numbers 75-33, 75-34, 75-35, 75-36, 75-37, 75-80, and 75-81. The wastes identified in these permits were in fact not accepted by Pagel's. (Howard Aff., ¶ 4; Appendix C). The amount in gallons which these permits constitute is 130,572 gallons or 2,611 drums. Conversion of gallons to drums and drums to gallons was based upon the assumption used in 40 C.F.R. Part 300, App. A, § 3.4, that one drum is the equivalent of 50 gallons. As the
(Footnote continued)

were authorized by the Illinois EPA to be disposed of at Pagel's, but in fact they never came there. Combination of the toxicity and persistence scores with hazardous waste quantity thus results in a score of 20, rather than 24 on this point.

The targets score was also recomputed. The groundwater use factor was scored by EPA at 3. Since the aquifer of concern is a drinking water source and no alternative municipal drinking water source is available, we have used that figure as well. The distance to nearest well/population served factor was scored at either 0 or 20. The zero, or best-case score, is based upon two facts readily available in the record. First, the area to the east of Pagel's is upgradient for purposes of groundwater flow and no wells in that area would therefore be affected. Second, there are no wells downgradient of Pagel's between the site and Killbuck Creek which EPA itself noted was a discontinuity of the shallow aquifer. (EPA backup "documentation record" for HRS worksheet, p. 5, Targets). The 20, or worst-case score, is the score EPA used for the distance to nearest well/population served factor at the Acme site across the road, which shares the same aquifer. This score should not be used, however, since those wells are

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15/ (continued)
EPA scorer noted, EPA's figure "would be lowered by quantities not actually delivered". Subtracting 2,611 drums of waste not actually received from the 2,734 drums supporting EPA's quantity estimate leaves a total of 126 drums actually received. The appropriate quantity score for 126 drums is 2. (These calculations are mathematically charted in Appendix J). Even this is a worst-case assumption, since it assumes that all the drums in question were full of hazardous substances in one-hundred-percent concentrations, which is not the case.

upgradient and could not possibly be affected by Pagel's. Combining the groundwater use factor of 3 with the distance to nearest well/population served factor results in a total targets score of either 9 or 29, depending on which "distance" score is used.

Performing the necessary mathematical computations with these figures results in an overall score of 0 for Pagel's assuming the best-case situation where a 0 score for containment is used. The worst-case score, assuming a score of 2 for a semi-permeable liner and 29 for targets would be 10.53. That worst-case score would be reduced to a 3.26 using a targets score of 9. In either case, this score warrants elimination of Pagel's from the NPL.[16]

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[16] Before learning that the revised reason for attribution was based upon the leaking leachate theory, Winnebago Reclamation reviewed the materials actually received based upon supplemental permits, and re-ranked its facility based upon a receipt of 60.81 tons of material containing phenols (supplemental permit #75-239). See Warzyn July 12, 1984, rescoring included in July 17, 1984, submittal to Richard Bartelt, USEPA, by Winnebago Reclamation Service, Inc. (For some reason, this permit does not appear in EPA's HRS support documentation, Reference Item 3, which includes other supplemental permits. Therefore a copy is attached to the Howard Aff., Appendix C hereto, as Exhibit 3). Based upon the much lower toxicity/persistence score of 14 for that material, the HRS score arrived at, using EPA's original targets estimate, was a worst case of 24.77. For the reasons set forth in section II above, which contradict the observed release theory, this phenol score has been recalculated based upon a threatened release. Using a threatened release, our revised hazardous waste quantity figure of 2 (based upon conversion factors set out in 40 C.F.R. Part 300, App. A, § 3.4, 60.81 tons of waste is the equivalent of 60.81 cu. yds., which results in a quantity factor of 2) and a targets figure of 9 or 29, the new worst case score for phenols would be either 7.37 (using the 29 targets figure) or 2.29 (using the 9 targets figure), again supporting the exclusion of Pagel's from the NPL.

IV. CONCLUSION

For the foregoing reasons, it appears that Pagel's Pit was proposed for listing on the basis of a series of negative inferences or assumptions, which can be rebutted by facts already developed. The existing evidence supports the single plume analysis as accurately describing the pattern of groundwater movement in the area. Furthermore, the revised HRS scorings based upon the present record, discussed above and set forth in Appendix J, show that Pagel's is neither causing nor threatening the type of harm required for NPL listing. It would be arbitrary and an abuse of discretion for the Agency to indict with the stigma of NPL listing an environmentally sound and well-managed facility on such a thin evidentiary record.

The hydrogeologic study currently under way is expected to provide additional evidence concerning groundwater movement and the source of contamination in and around the Acme Solvents and Pagel's areas. The present record supports exclusion of Pagel's from the NPL. Certainly, however, no action should be taken to include Pagel's on the NPL until the results of that pending study have been reviewed.

* * * *

Winnebago Reclamation Service, Inc. appreciates the opportunity to submit these comments in response to EPA's Notice of

Proposed Rulemaking. If you have any questions concerning any aspects of these comments, please feel free to contact us.

Respectfully submitted,

WINNEBAGO RECLAMATION SERVICE, INC.

By ______________________
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Of Counsel

APPENDIX A

Photographs Showing Construction of the Asphalt Liner and Cationic Sealer at the Winnebago Reclamation Service Inc. Solid Waste Disposal Site (Pagel's Pit)

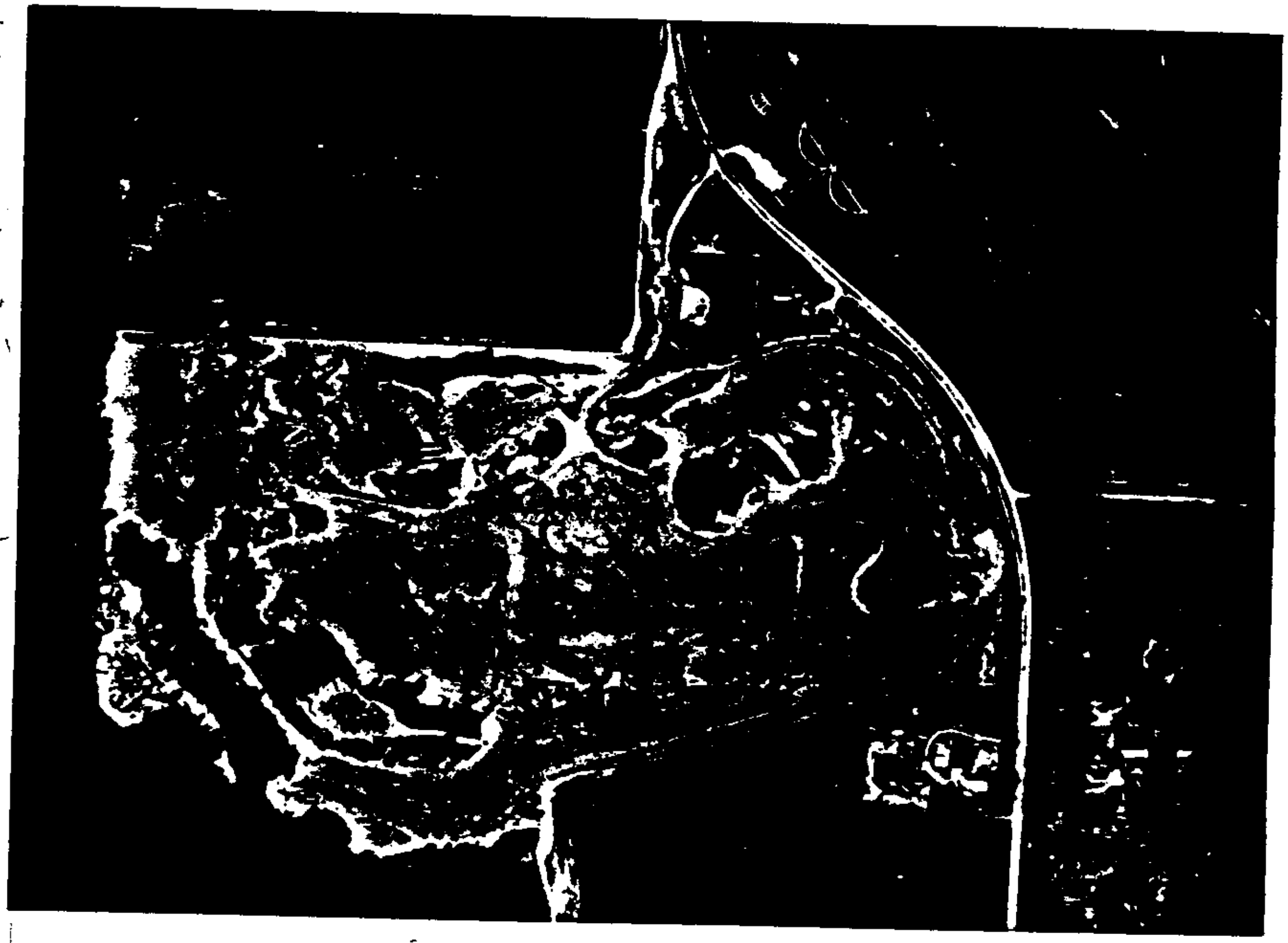


FIG. 1 Aerial photo of Pagel's Pit. (August, 1972)

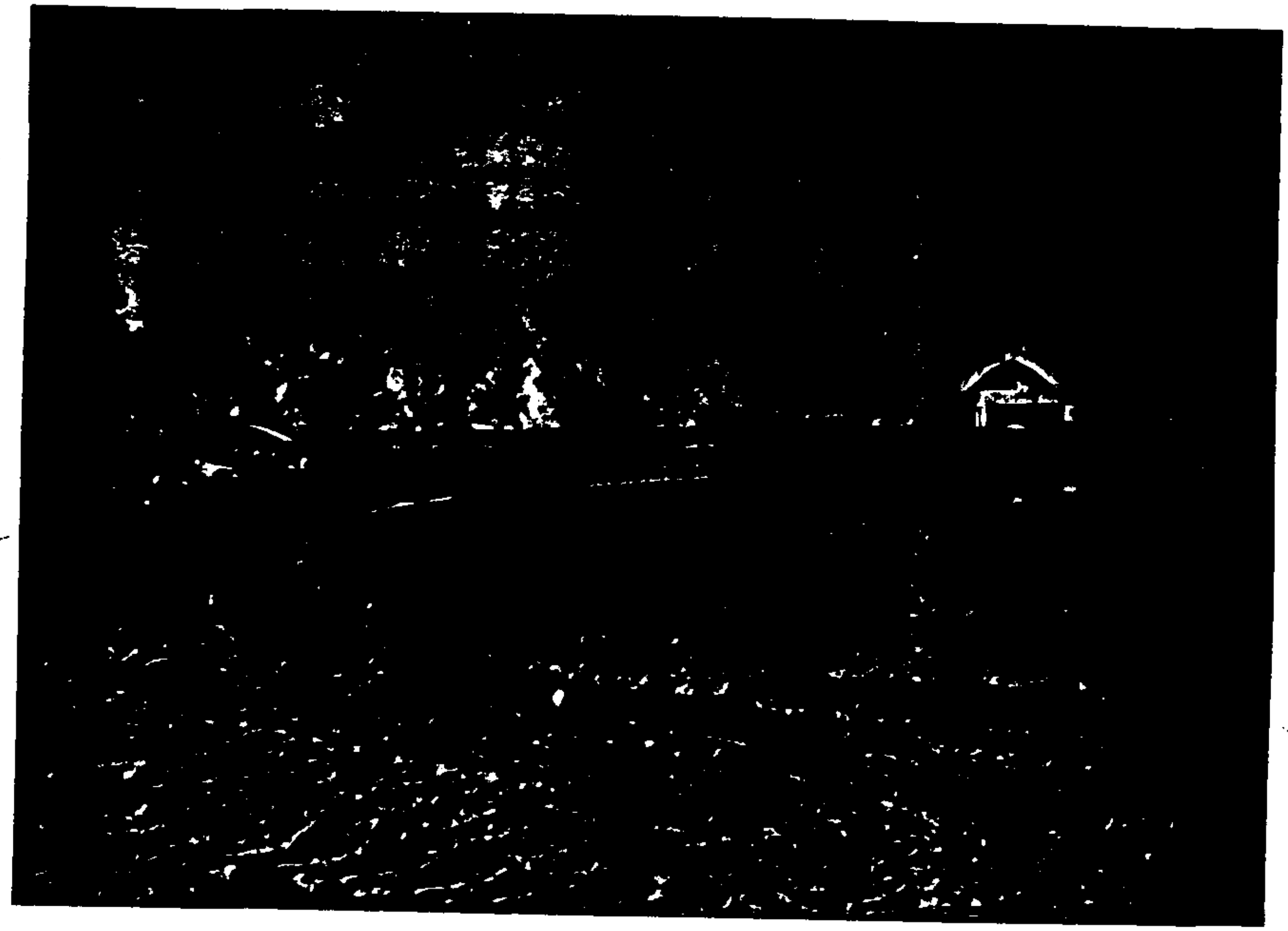


FIG. 2 Initial grading and dirt moving work for first unit. (June, 1972)

FIG. 3 Applying asphalt wall to side of unit, showing roller. (1977)

FIG. 4 Close-up view of asphalt compaction. (1977)

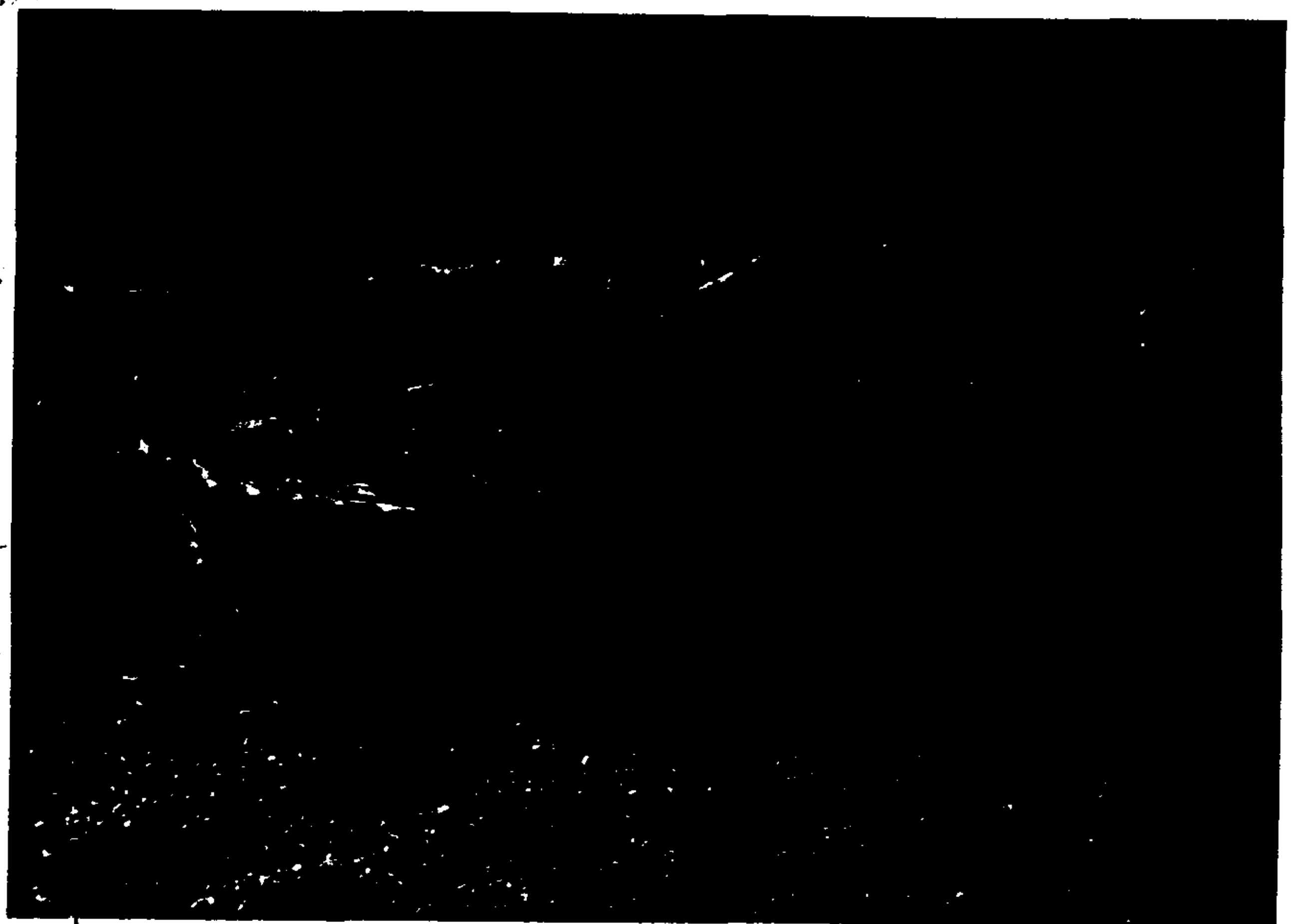


FIG. 5   Asphalt on wall and floor of pit. (1977)

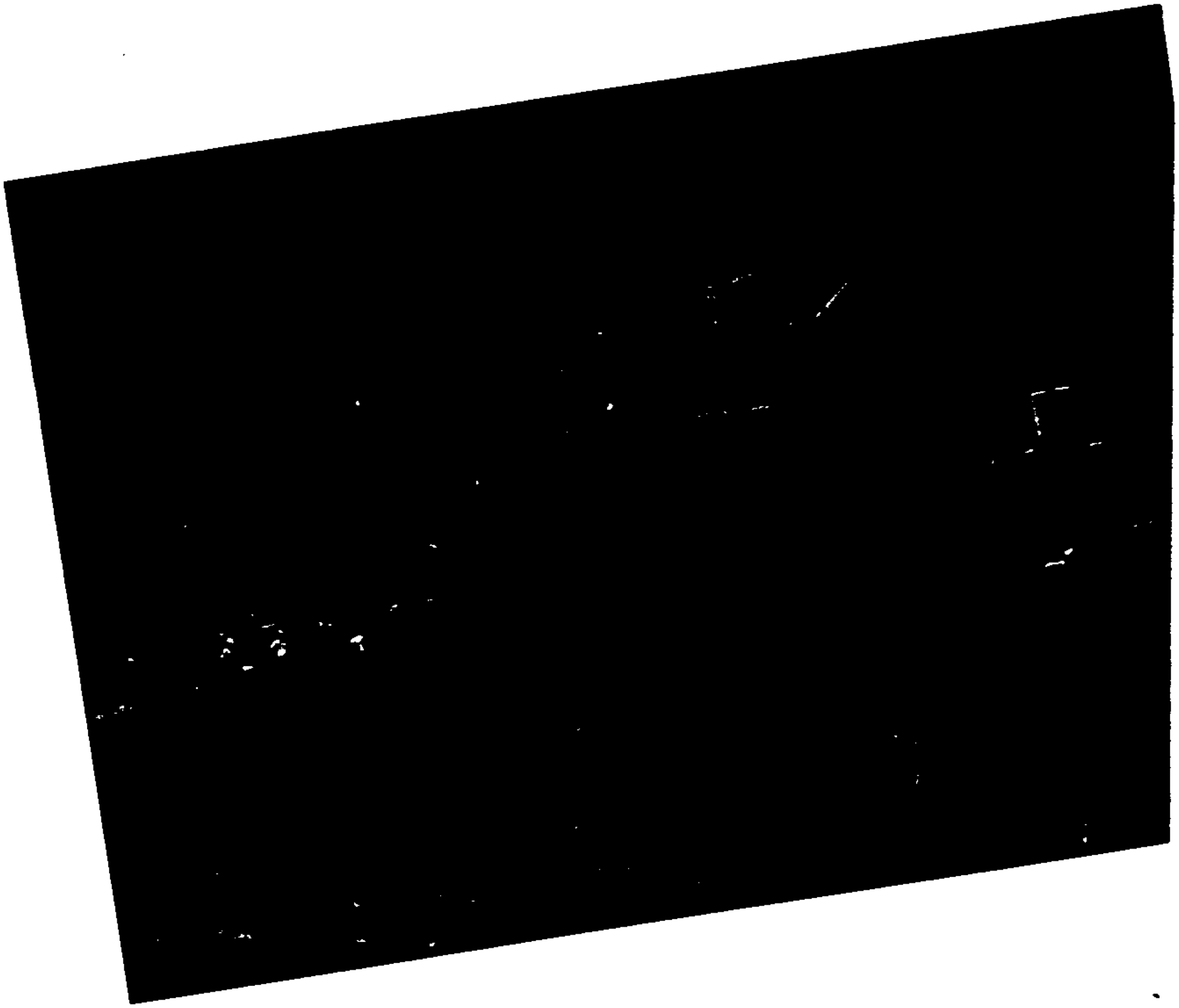


FIG. 6 Applying asphalt floor of pit. (1975)
Goes on top of a limestone layer (6"-8" th

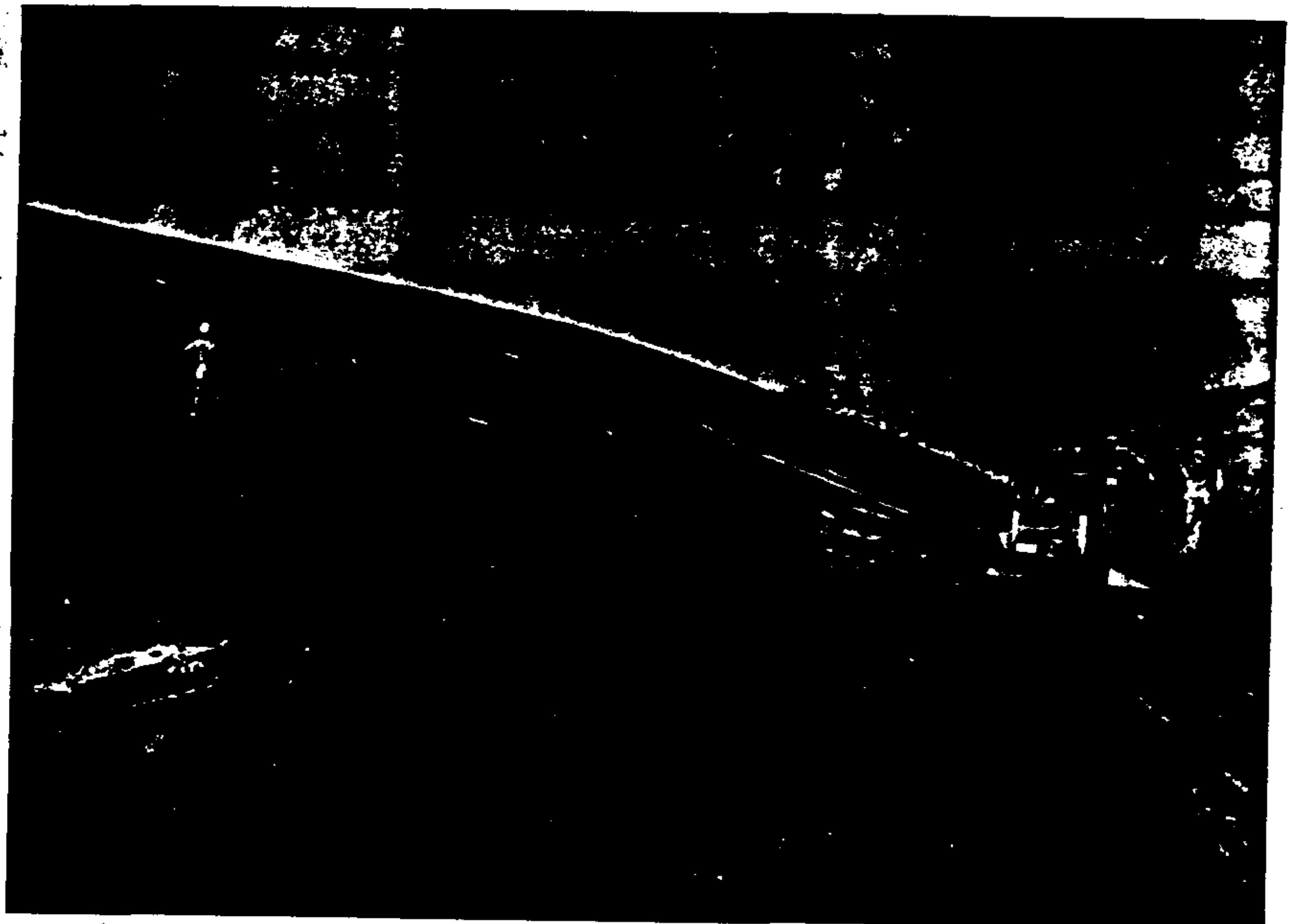


FIG. 7 Application of coal tar sealer to wall and floor.

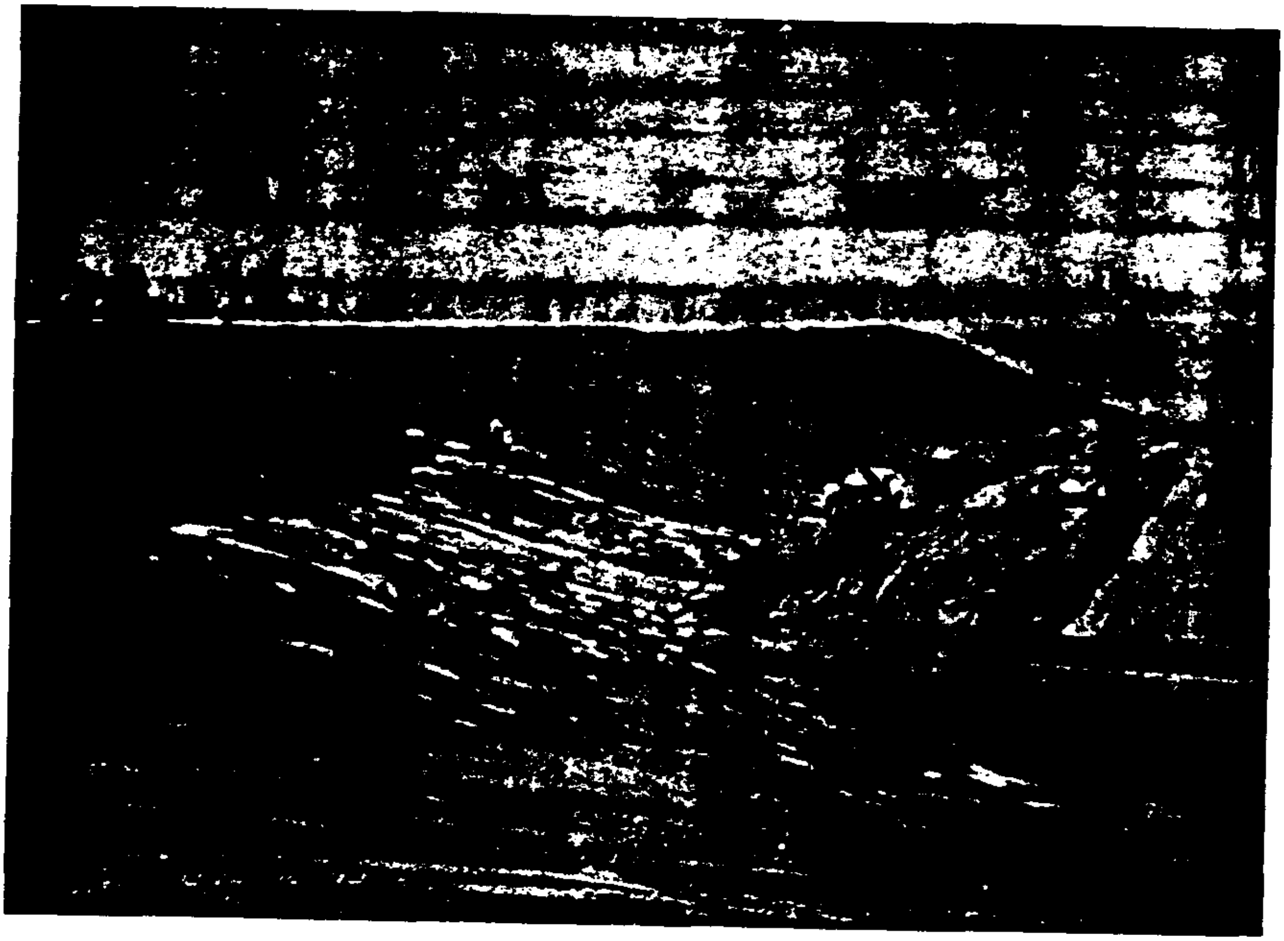


FIG. 8 Application of coal tar sealer to wall and floor.

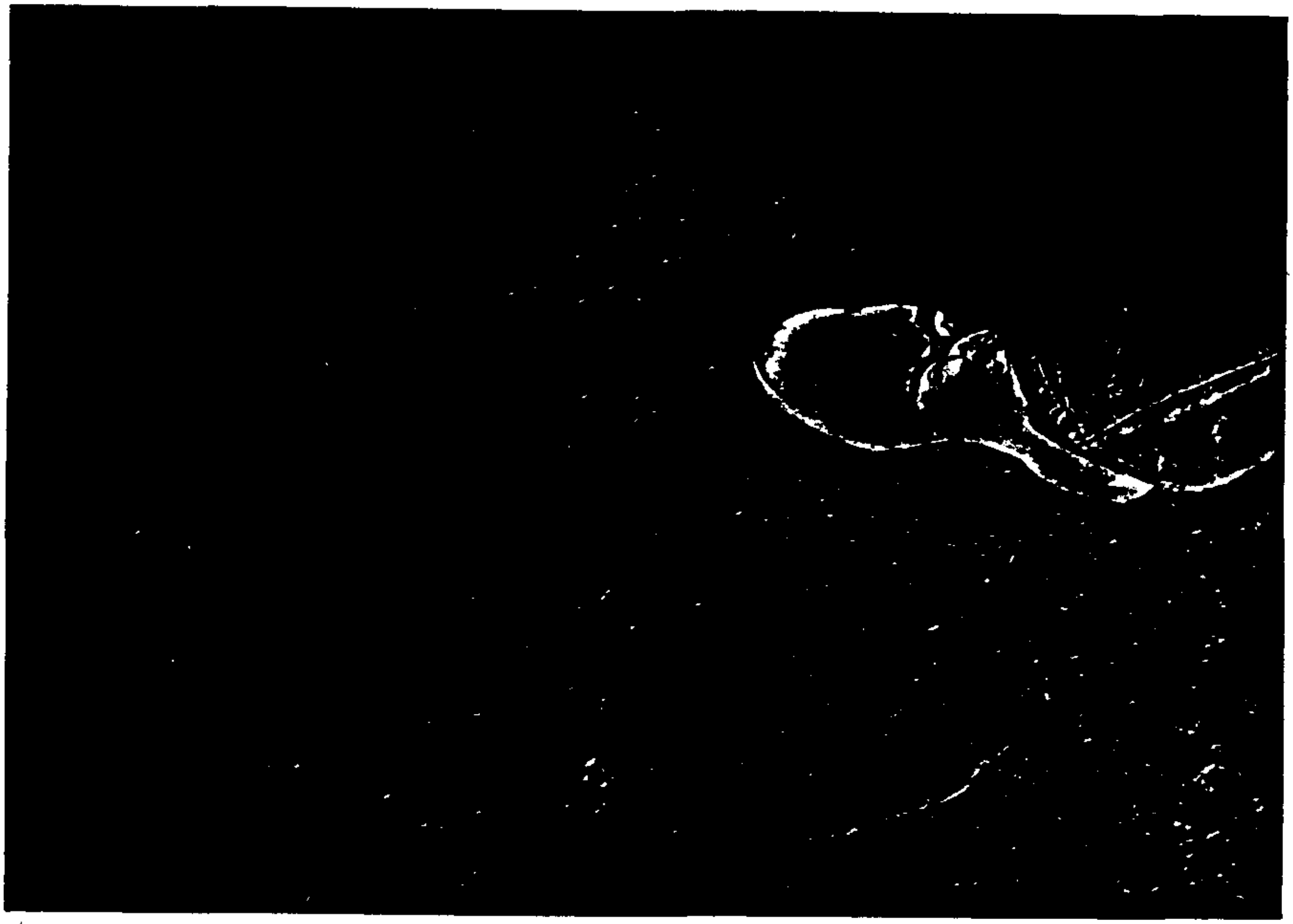


FIG. 9 Close-up of sealer on top of asphalt floor.

FIG. 10 Asphalt and sealed floor of pit. Beyond the grassy garbage wall is the asphalt liner wall.

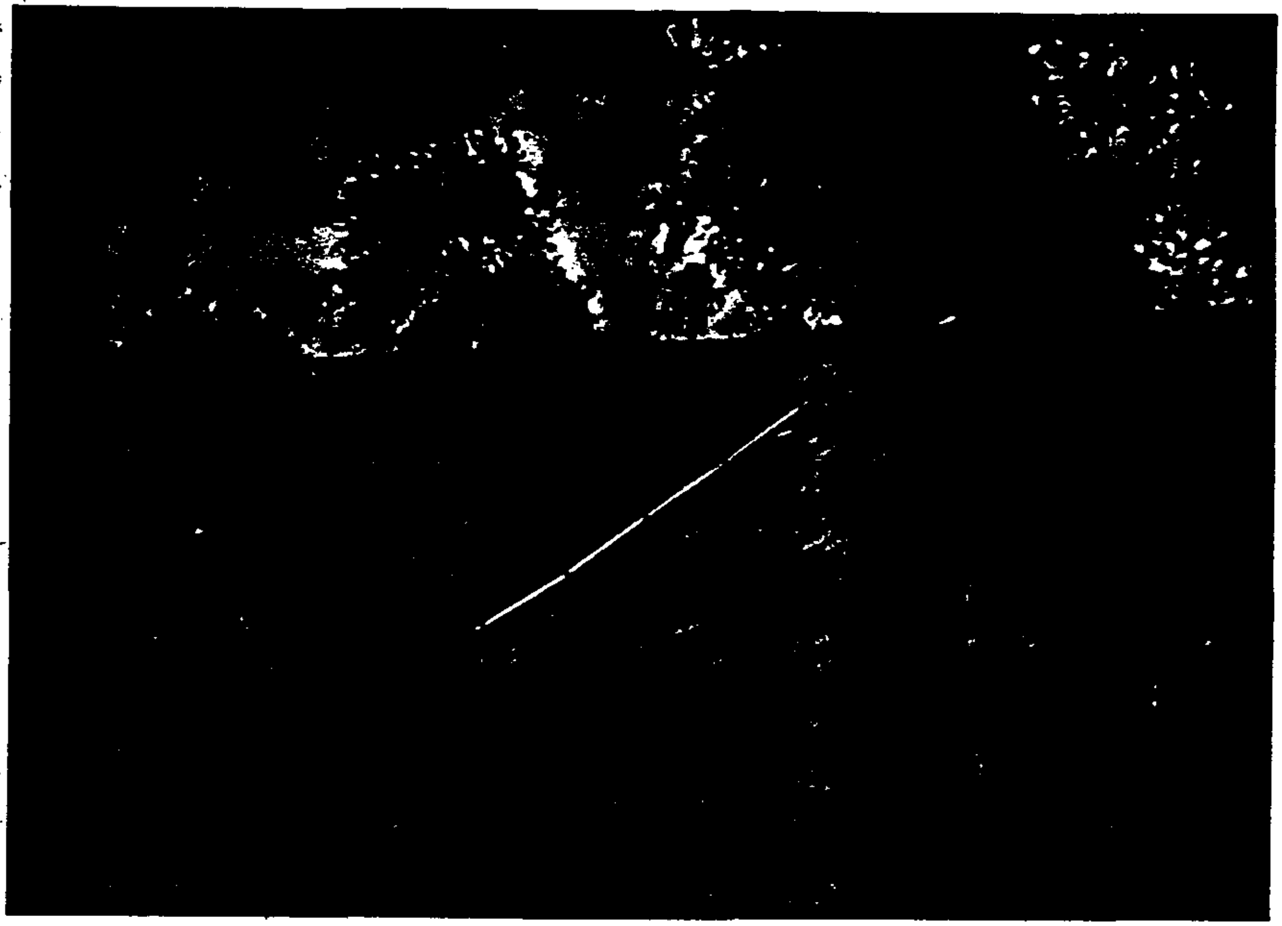


FIG. 11 Sand blanket on top of asphalt sealer. (1972)
Enhances leachate collection.

FIG. 12 Tires to protect leachate collection lines.

FIG. 13 Tires to protect leaching areas (same as FIG. 12). Provides some protection for lines also.

APPENDIX B

Solid Waste Disposal Site Permit Issued
by Illinois Environmental Protection Agency
for "Pagel's Landfill" Initially to
Rockford Blacktop Construction Company,
now Winnebago Reclamation Service Inc.

ENVIRONMENTAL PROTECTION AGENCY • STATE OF ILLINOIS
William L. Blaser, Director • Richard B. Ogilvie, Governor

April 7, 1972

WINNEBAGO COUNTY - Land Pollution Control
New Milford/Rockford Blacktop Co.
Permit #1972-24

Rockford Blacktop
Construction Company
600 Boylston Street
Loves Park, Illinois 61111

Gentlemen:

Permit is hereby granted to Rockford Blacktop Construction Company to install and operate a solid waste disposal site consisting of approximately 20 acres in the NE¼, Lot 10, Section 36, T.43N., R.1E., of the 3rd P.M., to handle domestic and industrial refuse all in accordance with the application and plans prepared by W. S. Howard: Said application consisting of 10 pages undated and received by the Environmental Protection Agency on April 5, 1972; said plans consisting of 6 pages entitled "Pagels Landfill", undated and received April 5, 1972.

The permit is issued subject to the standard conditions set forth on Page 2, attached hereto and incorporated herein by reference, and further subject to the following special conditions:

1. Solvents for the coal tar sealer shall be excluded from the landfill.

2. At least one ground-water monitoring well shall be installed within 60 days or before refuse is deposited in the landfill. A complete background chemical analysis for the components listed on the enclosure shall be submitted before refuse is deposited in the landfill.

Very truly yours,

ENVIRONMENTAL PROTECTION AGENCY

Douglas Andrews

Douglas Andrews, Manager, Permit Section
Division of Land Pollution Control

2200 Churchill Road • Springfield, Illinois 62706 • Telephone: 217-525-3397

This permit is granted pursuant to Section 39 of the "Environmental Protection Act", and the "Rules and Regulations for Refuse Disposal Sites and Facilities" as authorized therein, and is subject to the following conditions:

1. If any statement or representation in the application is found to be incorrect, this permit may be revoked and the permittee thereupon waives all rights thereunder.

2. There shall be no deviation from the approved plans and specifications unless additional or revised plans are submitted to the Environmental Protection Agency and a supplemental written permit issued therefor.

3. During or after the construction or the installation of refuse disposal site or facility for which a permit has been issued, any agent duly authorized by the Environmental Protection Agency shall have the right and authority to inspect such work and operation.

4. This authority, (a) shall not be considered to affect the title to the premises upon which the refuse or solid waste site or facility is to be located, (b) does not release the permittee from any liability for damage to person or property caused by or resulting from the installation, maintenance, or operation of the proposed site, (c) does does not release the permittee from compliance with other applicable statutes of the State of Illinois, or with applicable local laws, regulations or zoning ordinances.

5. Leachate from waste disposal site must be collected and adequately treated, all in accordance with Environmental Protection Act criteria.

6. Waste must be compacted in layers and covered daily, with six (6) inches of satisfactory material; surface(s) not receiving refuse must have one (1) foot of additional cover within a 60 day period.

7. Open dumping and open burning is prohibited.

8. This permit is void one year from the date of issue unless installation of this project has started on or prior to the date of expiration.

9. This permit is subject to review and change by the Environmental Protection Agency as deemed necessary to fulfill the intent and purpose of the Environmental Protection Act.

10. This permit is subject to revocation by the Environmental Protection Agency upon a finding by the Agency that any of the aforementioned conditions have been violated, or upon the violation of the Environmental Protection Act or any Rule or Regulation effective thereunder.

ENVIRONMENTAL PROTECTION AGENCY

Division of Land Pollution Control

BACKGROUND WATER SAMPLE ANALYSIS

Analysis for the following chemical characteristics shall be mandatory of at least one (1) ground-water sample taken from a monitor well on (or adjacent to) the newly-permitted landfill site. The sample shall be obtained BEFORE emplacement of refuse; the results of sample analysis shall be submitted promptly to this Agency. This water quality information shall be considered requisite for satisfactory completion of the application for permit requirements:

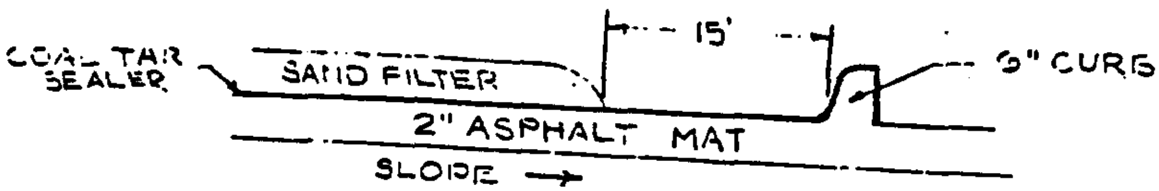
1. Alkalinity, as $CaCO_3$
2. Aluminum* (Al)
3. Arsenic (As)
4. Boron (B)
5. Bromides (Br^-)
6. Cadmium (Cd)
7. Calcium (Ca)
8. Chloride (Cl)
9. Chromium ---- Trivalent (Cr^{+3}) / Hexavalent (Cr^{+6})
10. COD
11. Copper (Cu)
12. Cyanide (CN)
13. Floride (F^-)
14. Hardness, as $CaCO_3$
15. Iron, dissolved (Fe)
16. Lead (Pb)

17. Magnesium (Mg)
18. Manganese (Mn)
19. Mercury (Hg)
20. Nickel (Ni)
21. Nitrate (NO_3)
22. pH
23. Phenol
24. Phosphate (PO_4)
25. Potassium (K)
26. ~~Radioactivity** Alpha Beta~~
27. Sodium (Na)
28. Specific Conductance ***
29. Sulfate (SO_4)
30. Total Dissolved Solids
31. Zinc

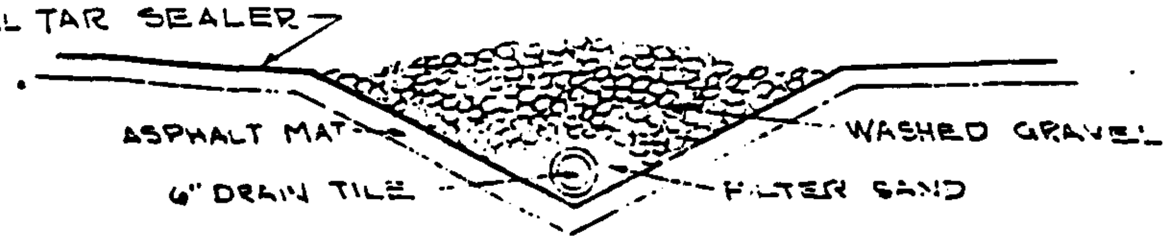
* All analyses for dissolved content unless otherwise indicated.
** Reported in pico curies per liter (pc/1).
***Reported in micromhos at 25°C.

LANDFILL OPERATION

The proposed landfill will be developed in 3-5 stages depending on the influx of refuse. Stage # 1 will consist of construction of the proposed liner over approximately 20% of the area shown on the drawings. The open side (west) of the liner will be curbed with a 6-inch asphalt curb and the coal tar sealer will be applied contiguously with that curb.



The curb and liner will be pitched so that all the water will flow directly to a holding tank. There will be no ponding on the asphalt liner. Any leachate or runoff water from this temporary tank will be hauled to the Rockford Sanitary District for disposal. After a 6-inch blanket of filter sand is placed, refuse will be disposed of uniformly over the entire area with the maximum of 4-foot lifts and deposited no closer than 15-feet from the open edge of the liner. Successive layers will maintain a 3 to 1 slope at the edge of each cell, and this slope will be covered with sand. As cell # 1 is filled above the liner, the final slopes will be covered with clay. As the top elevation is reached, the clay will be extended to form a 10 foot rim around the top of the pit. The remainder of the top will be covered with a minimum of 8 inches of sand graded to permit surface water to run through the compacted refuse. In joining cell # 2 with cell # 1, approximately 10 feet of cell # 1 will be pulverized with new asphalt added and then fused with the cell # 2 mat construction. During this construction the curb on cell # 1 will be eliminated and a new curb will be placed at the west edge of cell # 2. Cell #2 will be constructed in an identical manner with the exception that the collection ditch shown in the drawings will be filled with a 6-inch drain tile, filter sand and washed gravel as shown below:



DITCH DETAIL

HOLDING POND

At the time when the quantity of leachate becomes significant, a pump and forced main will be constructed to pump the leachate to the top of cell # 1 to promote the decomposition process. A diffuser will be placed at the end of the forced main to prevent a concentration of flow. In addition, a holding pond will be constructed completely outside of the landfill. This holding pond will be lined with clay and be used only in the case of a temporary breakdown of the pump or at the completion of the landfill when all refuse has been leached out. This pond will be situated between the landfill and the creek at the same elevation as the holding pond shown on the drawings. Fluid will get to this pond by gravity flow through an 18-inch pipe coupled with a gate valve. The holding pond, when used, will also be provided with a circulating pump for aeration.

MONITOR WELLS

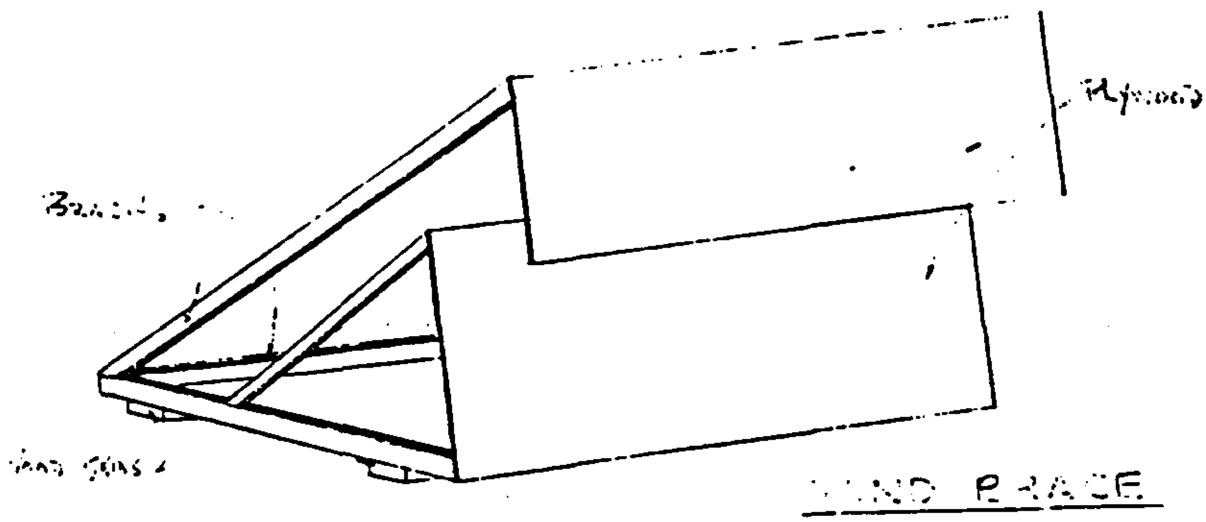
During the course of the landfill operation, a minimum of four monitor wells will be placed to allow continuous sampling of the ground water. If, at any time, these wells detect any leakage through the liner, volume wells will be installed downstream from the landfill, and the water will be pumped into the holding pond. This will continue until the apparent leaks can be sealed by either pressure grouting or some other suitable method. No water from any source will be allowed to flow into the creek until it meets the water purification standards of the State of Illinois.

FENCING

Before any refuse is accepted at the site, a 6 foot cyclone fence with 2 strands of barb wire will be constructed. One entrance and one exit will be provided to elimanate any unauthorized use of the site. The entrance and exit will be locked at any time the landfill site is closed.

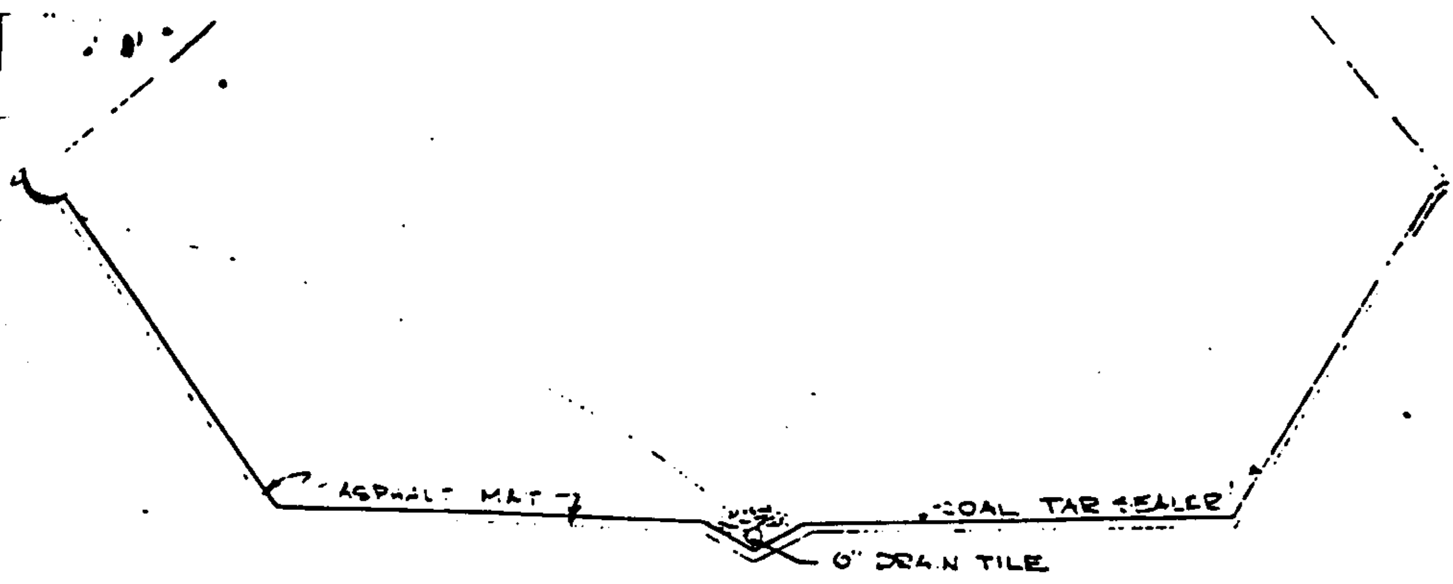
PREVENTION OF BLOWING LITTER

During the course of the landfill operation, trucks will be dumped individually by trained personnel on duty at the site. A mobile screen will be constructed to deflect the wind away from the dumping trucks as shown below:



COMPLETION OF LANDFILL OPERATIONS

At the completion of the landfill operation, the slope of the water table will conform to a line originating from the drain and extending to the sides and ends of the pit at elevations a minimum of 3 feet below the top of the liner as shown below:



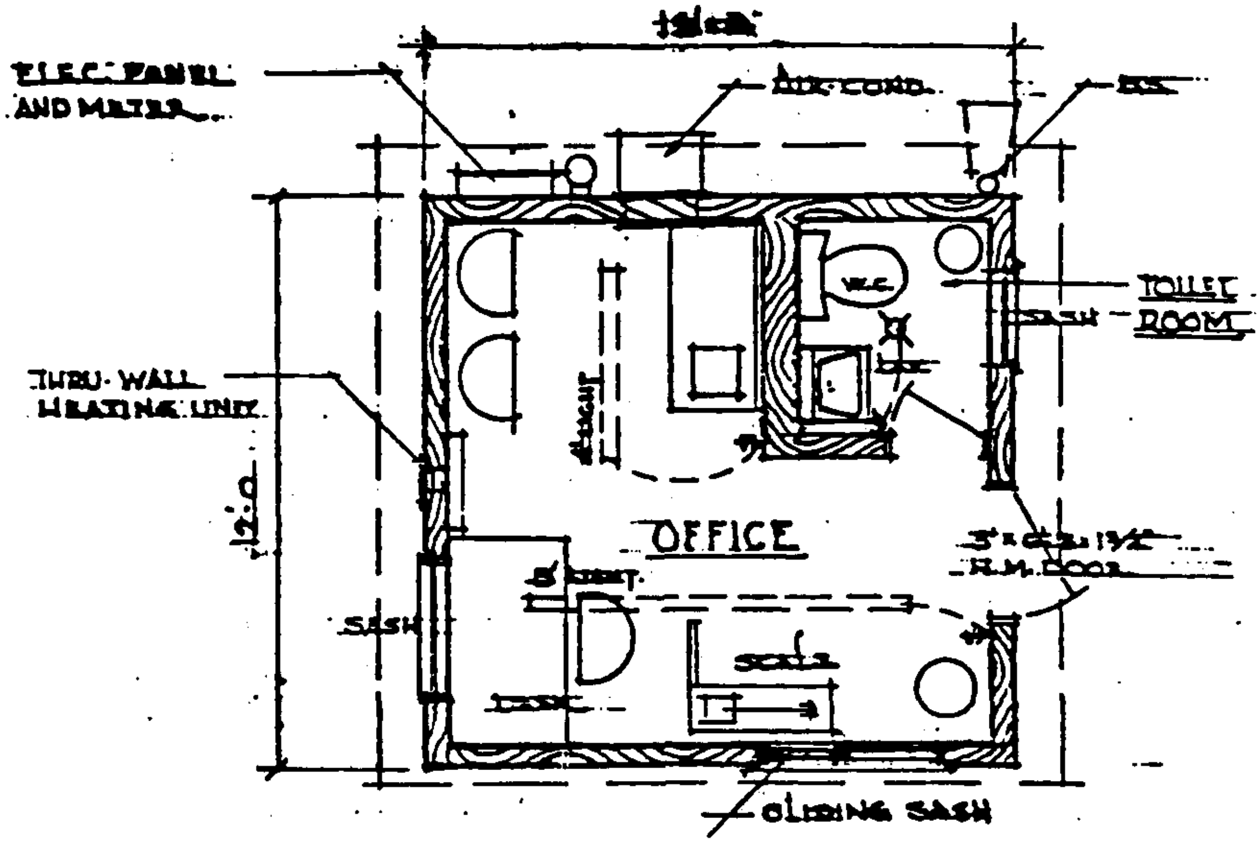
DRAIN TILE WILL BE PLACED AS NEED TO [illegible]

EARLY CLOSING OF LANDFILL SITE

If for any reason the landfill becomes inactive, all refuse will be covered and the closed leaching system will be continued until such time as the effluent will meet the water quality standards of the State of Illinois. The practice of rapid leaching will also be used when the landfill is completed to grades and elevations as shown in the final plan.

SCALE HOUSE AND EMPLOYEE FACILITY

A drawing of the proposed scale house is attached. This building will also be used as a facility for employees at the site. Provision has been made for heat and lighting. A wet toilet which will be hooked up to a septic system is included.



SCALE

A · SCALE HOUSE

SCALE 1/4" = 1'-0"

William L. Blaser, Director

2200 Churchill Road • Springfield, Illinois 62706 • Telephone: 217-525-3397

APPLICATION FOR PERMIT
FOR DEVELOPMENT AND OPERATION OF
SOLID WASTE MANAGEMENT SITE

And to Register Site in Accordance With The Environmental Protection Act

APPLICATION MUST BE SUBMITTED IN DUPLICATE

DO NOT WRITE IN THIS SPACE - FOR E.P.A. USE ONLY.

________________County - Land Pollution Control

________________ / ________________

Application Received:________________ Permit Number________________

Reviewed by: Geol.( ) Engr.( ) Op.( ) L.P.C. Region________________

Date:________________ Plan File Ref:________________

Letter Attached:________________ Permit: Granted________ Denied________

Notice To:________________ Date:________________

____

____

Type of Solid Wastes Site:
( ) Sanitary Landfill
( ) Incinerator
( ) Composting
( ) Other ________________

PART I - APPLICANT INFORMATION

A. SITE IDENTIFICATION

1. Name of Applicant Rockford Blacktop Construction Co.
(Person responsible for operation)

2. Address of Applicant 600 Boylston Street
(Street, P. O. Box, or R. R. #)

Loves Park | Illinois | 61111
City | State | Zip Code

Telephone: 815-877-7475
(Area Code) (Number)

3. Name of Land Owner Rockford Blacktop Construction Co.
(If same as above, so indicate)

4. Address of Land Owner 600 Boylston Street
(Street, P. O. Box, or R. R. #)

Loves Park — Illinois — 61111
City — State — Zip Code

5. Name of Site Pagels Pit

6. Address of Site Lindenwood Road
(Street, P. O. Box, or R. R. #)

Southeast of New Milford, Illinois
City — State — Zip Code

Winnebago County Rockford Township

7. Ownership (Check Applicable Boxes)

(X) Presently Owned
( ) To Be Purchased
( ) To Be Leased For ______ Years
( ) ______ Years of Lease Remaining

B. SITE BACKGROUND (Check Applicable Box or Boxes)

8. ( ) This is an existing operation begun _____(mo.) _____(yr.).
(X) This is a proposed new operation.
( ) This is a proposed new extension of an existing adjacent operation; Illinois EPA Permit No. __________; No Illinois Permit ( ).

PART II - LOCATION INFORMATION

A. ZONING AND LOCAL REQUIREMENTS

9. Present zoning classification of site Non Conforming Industrial.

10. Does present zoning of site allow the proposed usage? ( )Yes ( )No. see #11

11. Restrictions (if any) Zoning authority is presently being appealed in the courts.

12. Check applicable boxes which describe the use of adjacent properties surrounding site.

	Residential	Commercial	Industrial	Agricultural	Other*
a. North	( )	( )	( )	(X)	( )
b. East	( )	( )	( )	(X)	( )
c. South	( )	( )	( )	(X)	( )
d. West	( )	( )	( )	(X)	( )

* SPECIFY USE CLASSIFICATION ______________

13. a. Are there any permits, operational requirements, licenses, or other requirements or restrictions by any municipality, planning commission, county, county health department, state agency, or other governing body? List: Permit is needed from State of Illinois, Environmental Protection Agency

b. Have these requirements, licenses or restrictions been approved by the agency or governing body having jurisdiction? ( )Yes (X)No

c. If the answer to (b) is yes, include photocopies of supporting documents.

B. LOCATION

14. Attach a copy of the United States Geologic Survey (USGS) topographic quadrangle map of the area which contains the site.

Quadrangle Map Provided: Camp Grant Quadrangle (Name) 1949 (Date)

15. a. Outline on the USGS topographic quadrangle map the location and extent of the site.

b. Provide a legal description of the site. (Typewritten on attached sheet.)

NE 1/4 Lot 10 Quarter, ______ Quarter, ______ Quarter

of Section 36, Township 043, Range 001.

16. General topographic characteristic. (Flood Plain, Hillside, Field, Strip Mine, Quarry, Gully, etc.)
Briefly Describe: Sand and Gravel Pit

17. Plot the following information on the USGS quadrangle topographic map, if within the site or within a half-mile of outer perimeter of facility:

1. Wells (domestic, industrial, etc.)
2. Public water source (wells, stream, etc.)
3. Residences or residential areas, commercial facilities, industries, institutions, etc.
4. Other pertinent facilities not shown on topographic map such as diverted streams, strip mines, ponds, etc.

If scale of quadrangle map is insufficient, show on a separate topographic map.

A. SUBSURFACE INFORMATION

18. Provide subsurface information in sufficient detail to allow evaluation of the site for use as a solid waste disposal site. (Attach typewritten report.)

Not Applicable

B. SOIL BORINGS (Attach soil boring report.)

19. Provide a complete log (description) of each boring, along with all other pertinent data.

Not Applicable

20. Give the following information for bedrock, if encountered. (include in soil boring report)

a. Depth to bedrock
b. Type of bedrock
c. Name and age of bedrock formation (if known)

Not Applicable

C. MATERIALS SAMPLING DATA (include in soil boring report)

21. Give the following information for soil samples taken during the soil boring operation.

Not Applicable

a. Textural classification
b. Grain size distribution
c. Permeability
d. Void ratio
e. Ion-exchange capability

D. GROUND WATER (include in soil boring report)

22. Give the following information on ground water, if encountered.

Not Applicable

a. Depth to zone of saturation at time of boring.
b. Depth to zone of saturation minimum 24 hours after boring.
c. Direction(s) of ground water movement.

PART IV - LF - CONSTRUCTION PLANS AND SPECIFICATIONS

(SANITARY LANDFILL)

A. SITE DEVELOPMENT PLAN

23. Provide a detailed topographic map of the existing site (Scale 1:200 or larger) showing legal boundaries, with a minimum contour interval of five feet. This map should give details of all existing surface features such as buildings, ponds, streams, trees, rock outcrops, fire hydrants, underground and overhead utilities, sidewalks, drives, fences, culverts, streets, right-of-ways, and any other items of significance.

    Show location and elevation of soil borings as describ-d in Part III-A.B.20.

24. Provide a separate detailed topographic map of the developed site showing the following:

    a. Original and finished contours with a minimum contour interval of five feet.

    b. Surface features to be removed, altered or to remain. Designate areas to be used as source of cover material.

    c. New construction with location plans for berms, dikes, dams, earthen barriers, surface drainage ditches, culverts, fencing, access roads, utilities, walks, buildings, sanitary facilities, monitoring wells, streams, ponds, mines and any other special construction as may be required to comply with the provisions of the Rules and Regulations.

25. Provide cross-sectional or profile views (Scale 1:200 or larger) of the developed site to clearly indicate: (Minimum of three cross-sections required.)

    a. Proposed fill areas.

    b. Sequence of placement and total compacted thickness of each lift.

    c. Thickness of cover material for each lift. As Required

    d. Slope and width of working face for each lift. As Required

    e. Slope of completed fill with final cover in place. Minimum 4/1 slope

    f. Subsurface soil strata to a minimum depth of twenty feet below the base of the fill material. Glacial Till on Limestone Bedrock

    g. The top of the water table and direction of flow of the ground water. 5 feet southwest

    h. Earthen barriers, berms, dikes and other artificially created barriers, including essential dimensions of each. See Contour Map

    i. Subsurface leachate collection system, if used. Not Applicable

26. Provide plan view (Scale 1:200) and cross-sectional details of leachate collection and treatment system, if used, including the following information:

a. Type and location of subsurface collection devices.

b. Location, extent and surface elevation of treatment lagoon. Rockford Sanitary District

c. Written description of method of treatment. Rockford Sanitary District

d. Discharge point(s) of treated material. Rockford Sanitary District

27. Provide detailed plans including cross-section, of the access roads, buildings, culverts, fencing, monitoring wells, drainage ditches and any other features of significance.

B. SCHEDULE OF CONSTRUCTION

28. Attach a typewritten narrative supplemented by indications on the plans of the sequence of areas to be filled. Estimate the date of beginning and ending each phase of the construction and operation.

C. CONSTRUCTION REQUIREMENTS

29. Attach a typewritten narrative supplemented by indications on the plans of provisions to be made for:

a. Prevention of surface - or ground - water pollution.

b. Control of gas migration.

c. Elimination of flood hazard.

d. Employee facilities.

e. Access to the site.

f. Measuring quantity of solid waste delivered to the site.

A. SOURCE AND VOLUME

30. Indicate the estimated volume of each of the following sources and types of solid waste the facility will handle during each day of operation; each week of operation; each year of operation.

	SOURCE	TYPE	DAILY VOLUME	WEEKLY VOLUME	YEARLY VOLUME
a.	Residential		188 TN	942 TN	49,000 TN
b.	Commercial		88 TN	442 TN	23,000 TN
c.	Industrial		62 TN	308 TN	16,000 TN
d.	Agricultural				Minimal
e.	Other (Describe)				No other

31. At the above rate of use, what is expected useful life of the facility?

10-15 Years.

32. Will sewage sludge or any other hazardous waste be accepted? ( )Yes (X)No

33. What types of hazardous waste will be accepted? (Describe Briefly)

Hazardous waste will not be accepted at the site

B. DESCRIPTION OF OPERATING PROCEDURES

34. Attach a typewritten plan of operation to accompany this application. This plan should include the following subjects:

a. Method of landfilling (Trenching, area fill)

b. Time schedule for filling and daily covering

C. OPERATING REQUIREMENTS

35. Attach a typewritten description of provisions for:

a. Personnel for supervision and operation

b. Traffic control

c. Designation of unloading area

d. Cell size and construction

35. e. Provisions for blowing litter control

f. Rodent control

g. Fly control

h. Bird control

i. Dust control

j. Odor control

k. Management of surface water

l. Erosion control

m. Final cover and final slopes.

n. Monitoring program for groundwater and gas

o. Salvage and scavenging operations

36. Attach a typewritten description of methods for handling any special or hazardous wastes which will be accepted at the site.

37. Provide a list of equipment to be used for landfill operation:

ITEM(S)	MODEL NUMBER	NO. OF UNITS IN OPERATION	DESCRIPTION
	SEE ATTACHED SCHEDULE		

38. Attach a typew... of provisions for final grading and revegetation of the ... areas. State what arrangements will be made for the repair of eroded, cracked and uneven areas for a period of not less than five years following completion of the landfill.

39. By signature affixed to this Application for Permit the applicant affirms his intent to record description and plan of the completed site with the county official responsible for maintaining titles and records of the land, in accordance with the Rules and Regulations of this Agency, if granted a Development and/or Operating Permit.

I hereby affirm that all information contained in this Application true and accurate to the best of my knowledge and belief.

Rockford Blacktop Construction Co.

Signature of Applicant: G. C. Smaloney, Secretary

Attest: ____________________

Signature of Engineer: ____________________ (seal)

Illinois Reg. No.: ____________________

Attest: ____________________

b. The area will be signed to comply with safety regulations and insure smooth traffic flow. We propose a one-way traffic pattern. A man will be assigned to make sure that trucks are dumped at the correct fill area.

c. There will be adequate signs and personnel to designate area and supervise unloading.

d. As shown on plans.

e. Adequate permanent and temporary fencing will be available to control blowing litter. Water will be available at the site to wet down the refuse if needed.

f,g,h. The area will be treated with chemicals as needed to control rodents, flies, insects and birds.

i. Dust will be controlled with water which will be available at the site.

j. Odor will be controlled by use of suitable cover material.

k. For management of surface water see plans.

l. As per plan.

m. Final cover on completed site will be 6 inches of sand fill and 2 feet of clay. Final slopes will be a minimum 4 to 1. The area will be seeded so as to prevent erosion caused by surface water.

n. Monitor wells will be placed as required.

o. There will be no salvage or scavanging operations conducted by the landfill operator, nor will such operations be allowed to outsiders.

<u>Part V - Item 36</u>

No hazardous wastes will be accepted at the site.

<u>Part V - Item 38</u>

For final cover and grading, see Item 35 m. The area will be maintained by the operator in case of eroded or uneven areas. No cultivated crops will be planted on the site.

C

APPENDIX C

Affidavit of Charles J. Howard, President of Winnebago Reclamation Service Inc.

EXHIBIT 1

TO

AFFIDAVIT OF CHARLES J. HOWARD

October 16, 1972

Mr. Douglas Andrews
Land Pollution Division
Environmental Protection Agency
2200 Churchill Road
Springfield, Ill. 62706

Dear Doug:

I am enclosing a copy of a letter which we received from Lyle Porter regarding Quality Metal Finishing Company, Byron, Illinois. I am sure you are familiar with the case.

I would like your judgement as to what we should do about this. If you consider the waste to be "non-hazardous", we will apply for an amendment to our permit. If, however, in your opinion, this waste is hazardous or might be hazardous to our landfill, we will let Mr. Porter know that we would rather not accept the waste.

Very truly yours,

Neil A. Maloney, Secretary
Rockford Blacktop Construction Co.

NAM/cb
Enc.

(B)

February 7, 1975

Mr. Tom Cavanaugh
Supplemental Permit Section
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Re: Winnebago County
Land Pollution Control

Dear Mr. Cavanaugh:

Congratulations on the appointment of your new position. I am looking forward to working with you to secure supplemental permits.

I am including in this envelope a summary of all of the supplemental permits I have received, so that you have a check with the files you inherited. You will find this summary to be quite extensive. For every gallon of liquid I have received at our landfills, I have first secured a permit. I do this primarily to comply with the regulations, but also to check that I do not in any way jeopardize the operation of the landfills. My primary concern is disposal of solid refuse in a sanitary manner. I only allow liquid disposal as a supplemental operation to accommodate business. If you feel that by disposing of some liquids my land fill permit would be endangered, please let me know.

Enclosed please find:

1. Summary of supplemental permits.
2. Application for Belvidere Hardware.
3. Sample letters. One I send to the E.P.A. and the other I send to potential customers. Any modifications of these letters you desire will be implemented.
4. Copy of application for phosphate sludge disposal.
5. Copy of application for Cala Products.

Very truly yours,

CJH/lh

CHUCK HOWARD
Rockford Blacktop Construction Co.

EXHIBIT 2

TO

AFFIDAVIT OF CHARLES J. HOWARD

217-782-6760

February 24, 1975

IN REPLY REFER TO: 20180801
WINNEBAGO COUNTY - Land Pollution Control
New Milford/Rockford Blacktop
Permit No. 1972-24
Supplemental Permit No. 75-33

Rockford Blacktop Construction Co.
600 Boylston Street
Loves Park, Illinois 61111

Gentlemen:

Supplemental permit is hereby granted to Rockford Blacktop to accept a 1592-gallon backlog and 1040 gallons per week of industrial sludges, generated by Gale Products, Galesburg, Illinois all in accordance with the plans prepared by Rockford Blacktop, dated December 10, 1974 and received by the Agency on February 7, 1975. This supplemental permit is further subject to the following special conditions:

The backlog material as well as the routinely generated material shall be disposed at the working face in a ratio that does not exceed 10 gallons per cubic yard of solid waste.

This permit shall expire one year from the date of issuance, subject to renewal upon prior approval of the Agency.

Except as modified in the above documents, the site shall be operated in accordance with the terms and conditions of Permit No. 1972-24 dated April 7, 1972.

Very truly yours,

ENVIRONMENTAL PROTECTION AGENCY

C E Clark

C. E. Clark, Manager
Permit Section
Division of Land Pollution Control

TEC:ds
cc's/-Region 1
-File

(5) GALE PRODUCTS
COPY

ROCKFORD BLACK TOP CONSTRUCTION CO.

ALL TYPES OF ASPHALT PAVING
GRADING CONTRACTORS
STONE & GRAVEL PRODUCERS
PREMIXED PATCHING

10 BOYLSTON STREET • LOVES PARK, ILL. 61111 • Phone 877-[redacted] 956

December 10, 1974

Tom Clark
Supplemental Permit Section
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Re: Winnebago County
Land Pollution Control

Dear Mr. Clark:

I am requesting permission to dispose of the following material:

Landfill: Pagels; 1972-24; 20180801

Source: Gale Products

Description: See next two pages

Quantity: See Red ink on next page; total of 398-55 open top drums containing approximately 40 gal. each are on hand as a backlog. Approximately 26 drums are generated per week.

Handling: Dump with household refuse.

Very truly yours,

CHARLES J. HOWARD, Landfill Manager
Rockford Blacktop Construction Co.

SALE PRODUCTS

TEL. (309) 343-0141

December 3, 1974

Mr. J. C. Kullberg, President
Interstate Pollution Control, Inc.
1525 - 9th Street
Rockford, Illinois 61108

Dear Mr. Kullberg:

The following is a description of the sludge which we remove from our effluent treatment systems. As we discussed during your recent visit, there are three such units each having a different composition of sludge. Therefore, an analysis is given for each process.

<u>Acid-Alkali Neutralization</u>		
Solids	35-40%	1200 GAL BACKLOG
Composition		
Calcium Sulfate	1.6%	
Calcium Hydroxide	98.3%	80 GAL/WK
Iron Hydroxide	1.3%	
Nickel Hydroxide	.4%	
pH	7.5-8.5	
<u>Cyanide Destruction Unit</u>		
Solids	35-40%	
Composition		6160 GAL BACKLOG
Calcium ~~Hydroxide~~ CARBONATE (Water Hardness)	99+%	
Cadmium Hydroxide	Trace	400 GAL/WK
pH	9.5-10.5	
<u>Chromium Precipitation Unit</u>		
Solids	35-40%	
Composition		
Barium Chromate	97.6%	6160 GAL BACKLOG
Chromium (Tri valent)	1.4%	
Barium Carbonate	1.0%	400 GAL/WK
pH	6.5-7.5	

Paint Booth Waste (Water Type)

Solids	80%	2400 GAL BACKLOG
Composition		
Alkyd Resin Solids	96%	160 . GAL/WK
Pigments	4%	
pH	9.0-9.5	

If there are any questions concerning the above or additional information is required, we will try to supply it.

Sincerely,

GALE PRODUCTS

Paul Beardsley gt

G. Paul Beardsley
Chemical Engineer

GPB:gt

cc: W. Boles
M. Kirkenmeier
D. McGrew

3

217/782/6760

February 25, 1975

IN REPLY REFER TO: 20180801
WINNEBAGO COUNTY - Land Pollution Control
New Milford/Rockford Blacktop
Permit No. 1972-24
Supplemental Permit No. 75-34

Rockford Blacktop Construction Company
600 Boylston Street
Loves Park, Illinois 61111

Gentlemen:

Supplemental Permit is hereby granted to Rockford Blacktop Construction Company to accept 18 fifty-five gallon drums of metal hydroxide sludge generated by Commercial Wire all in accordance with the plans prepared by Charles J. Howard, landfill manager, Rockford Blacktop, dated January 20, 1975 and received by the Agency on January 21, 1975. This supplemental permit is further subject to the following special conditions:

Waste shall be disposed of in accordance with Supplemental Permit No. 74-130.

This permit shall expire one year from the date of issuance, subject to renewal upon prior approval of the Agency.

Except as modified in the above documents, the site shall be operated in accordance with the terms and conditions of Permit No. 1972-24 dated April 7, 1972.

Very truly yours,

ENVIRONMENTAL PROTECTION AGENCY

C E Clark

C. E. Clark, Manager
Permit Section
Division of Land Pollution Control

TEC:ch
cc Region I
File

= 1615 cu yds/day
(at 10 gal/cu.yd).
liquid waste allowed = 16,150 g

ROCKFORD BLACK TOP CONSTRUCTION CO.

ALL TYPES OF ASPHALT PAVING
GRADING CONTRACTORS
STONE & GRAVEL PRODUCERS
PREMIXED PATCHING

0 BOYLSTON STREET • LOVES PARK, ILL. 61111 • Phone 877-956[redacted]

January 20, 1975

Tom Clark
Supplemental Permit Section
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Supp Permit

Re: Winnebago County
Land Pollution Control

Dear Mr. Clark:

1972-24

I am requesting permission to dispose of the following material:

Landfill: Pagel Pit, 20180801

Source: Commercial Wire

Description: See next page. This material is from the same process, Supplemental permit no. 74-130 was issued for this.

Quantity: 18 - 55 gal. drums

Handling: Placed with household refuse

Very truly yours,

Charles J. Howard

CHARLES J. HOWARD, Landfill Manager
Rockford Blacktop Construction Co.

Test Number 5-112

MET-Chem Consultants, Inc.
802 Cedar Street
Rockford, Illinois 61102
815-964-8518

From: Commercial Mike [illegible]
1527 Broadway
Rkfd. Ill. 61101

Sample I.D. Carbonate Sludge
Sample Date
[illegible]

TEST RESULTS

Sample Received 1-9-75

Sample Tested 1-13-75

Acidity

Alkalinity

Aluminum

BOD_5

Boron

Cadmium

Carbon

Chlorine

Carbonates = 2.6 %

Chrome

COD

Coliforms

Copper

Cyanide

Total .15 %

Free

DO

Flash Point

Fire Point

Humidity Resistance

Iron

Lead

Molybdenum

Nickel

Nitrogen

Oil & Grease

Phosphorus

Salt Spray Res.

Silicon

Silver

Solids

Specific Gravity

Sulfur

Surface Tension

Viscosity

Zinc .042 %

Other

Results submitted by:

[illegible signature]

217/782/6760

February 25, 1975

IN REPLY REFER TO: 20180801
WINNEBAGO COUNTY - Land Pollution Control
New Milford/Rockford Blacktop
Permit No. 1972-24
Supplemental Permit No. 75-35

Rockford Blacktop Construction Company
600 Boylston Street
Loves Park, Illinois 61111

Gentlemen:

Supplemental Permit is hereby granted to Rockford Blacktop to accept 20,000 gallons per year of metal sludge, generated by Belvidere Hardware, Belvidere, Illinois, all in accordance with the plans prepared by Charles J. Howard, Rockford Blacktop, dated February 7, 1975 and received by the Agency on February 13, 1975. This supplemental permit is further subject to the following special conditions:

Waste shall be disposed of at the working face of the landfill in a ratio not to exceed 10 gallons per cubic yard of solid waste.

This permit shall expire one year from the date of issuance, subject to renewal upon prior approval of the Agency.

Except as modified in the above documents, the site shall be operated in accordance with the terms and conditions of Permit No. 1972-24 dated April 7, 1972.

Very truly yours,

ENVIRONMENTAL PROTECTION AGENCY

C.E. Clark

C. E. Clark, Manager
Permit Section
Division of Land Pollution Control

TEC:ch
cc Region 1
File

(2) Application ... ...

ROCKFORD BLACK TOP CONSTRUCTION CO.

ALL TYPES OF ASPHALT PAVING
GRADING CONTRACTORS
STONE & GRAVEL PRODUCERS
PREMIXED PATCHING

OYLSTON STREET • LOVES PARK, ILL. 61111 • Phone 877-[redacted]

2-7-75

Mr. Clark
Supplemental Permit Section
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Re: Winnebago County
Land Pollution Control

Dear Mr. Clark:

I am requesting permission to dispose of the following material:

Landfill:	Pagels
Source:	Belvidere Hardware
Description:	See Attached Sheet
Quantity:	20,000 Gal./yr.
Handling:	Mix with refuse

Very truly yours

CHARLES J. HOWARD, Landfill Manager
Rockford Blacktop Construction Co.

75-3

MET-Chem Consultants, Inc.
802 Cedar Street
Rockford, Illinois 61102
815-964-8518

Sample I.D. Sludge (Belvidere Hardware)
Sample Date 1-30-75

TEST RESULTS

Sample Received 1-30-75 Sample Tested 1-31-75

Acidity

Alkalinity

Aluninum

OD5

Boron

Cadmium

Carbon

Chlorine

Chrome 10.0 ppm

BOD

Coliforms

Copper 4.0 g/l

Cyanide

Total 124.8 ppm

Free

DO

Flash Point none

Fire Point

Humidity Resistance

Iron

Lead

Molybdenum

Nickel

Nitrogen

Oil & Grease

Phosphorus

Salt Spray Res.

Silicon

Silver

Solids Total = 40.7 g/l

Specific Gravity

Sulfur

Surface Tension

Viscosity

Zinc 370.0 ppm

Other

pH = 8.9

Results submitted by:

G. Nausner

217/782/6760

February 25, 1975

IN REPLY REFER TO: 20180801
WINNEBAGO COUNTY - Land Pollution Control
New Milford/Rockford Blacktop
Permit No. 1972-24
Supplemental Permit No. 75-36

Rockford Blacktop Construction Company
600 Boylston Street
Loves Park, Illinois 61111

Gentlemen:

Supplemental Permit is hereby granted to Rockford Blacktop Construction Company to accept 16,000 gallons per year of Caustic Sludge, generated by Automatic Electric, Rockford, Illinois all in accordance with the plans prepared by Rockford Blacktop, dated February 10, 1975 and received by the Agency on February 13, 1975. This supplemental permit is further subject to the following special conditions:

Waste shall be disposed of at the working face of the landfill at a rate not to exceed 10 gal./yd^3 of solid wastes.

This permit shall expire one year from the date of issuance, subject to renewal upon prior approval of the Agency.

Except as modified in the above documents, the site shall be operated in accordance with the terms and conditions of Permit No. 1972-24 dated April 7, 1972.

Very truly yours,

ENVIRONMENTAL PROTECTION AGENCY

C. E. Clark

C. E. Clark, Manager
Permit Section
Division of Land Pollution Control

TEC:ch
cc Region I
File

ROCKFORD BLACK TOP CONSTRUCTION CO.

6(BOYLSTON STREET • LOVES PARK, ILL. 61111 • Phone 877-953

ALL TYPES OF ASPHALT PAVING
GRADING CONTRACTORS
STONE & GRAVEL PRODUCERS
PREMIXED PATCHING

February 10, 1975

Mr. Clark
Supplemental Permit Section
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Re: Winnebago County
Land Pollution Control

logged 2/20/75 JS

Dear Mr. Clark:

I am requesting permission to dispose of the following material:

Landfill: Pagels 1972-24

Source: Automatic Electric

Description: Caustic Sludge - see attached sheet

Quantity: 16,000 Gal. per year

Handling: Mix with household refuse

RECEIVED
FEB 13 1975
ILL. E.P.A. - D.L.P.C.
STATE OF ILLINOIS

Very truly yours,

CHARLES J. HOWARD, Landfill Manager
Rockford Blacktop Construction Co.

75-56

Test Number 3-163

M I-Chem Consultants, Inc.
802 Cedar Street
Rockford, Illinois 61102
8 5-964-8518

1525-9th St.
Automatic Electric
Sample I.D. caustic
Sample Date

TEST RESULTS

Sample Received 2-7-75 Sample Tested 2-7-75

Acidity

Alkalinity

Aluminum

5

Boron

Cadmium

Carbon

Chlorine

Chrome 49.0 ppm

D

Coliforms

Copper 24.0 ppm

Cyanide

Total

Free

DO

Flash Point none

Fire Point

Humidity Resistance

on

Lead

Molybdenum

Nickel

Nitrogen

Oil & Grease

Phosphorus

Salt Spray Res.

Silicon

Silver

Solids Total = 115.1 g/l

Specific Gravity

Sulfur

Surface Tension

Viscosity

Zinc 423 ppm

Other

pH = 13.1

Results submitted by:

G. Naucauer

217/782/6760

February 25, 1975

IN REPLY REFER TO: 20180801
WINNEBAGO COUNTY - Land Pollution Control
New Milford/Rockford Blacktop
Permit No. 1972-24
Supplemental Permit No. 75-37

ILL. E.P.A. - D.L.P.C.
STATE OF ILLINOIS

Rockford Blacktop Construction Company
600 Boylston Street
Loves Park, Illinois 61111

Gentlemen:

Supplemental Permit is hereby granted to Rockford Blacktop Construction Company to accept 18,000 gallons per year of acid sludge generated by Automatic Electric, Rockford, Illinois all in accordance with the plans prepared by Charles J. Howard, Landfill Manager, Rockford Blacktop, dated February 10, 1975 and received by the Agency on February 14, 1975. This supplemental permit is further subject to the following special conditions:

This permit will expire one year from the date of issuance, subject to renewal, upon prior approval of the Agency.

Due to the low pH of this material, it is recommended that employees charged with its disposal take precautionary measures and wear protective clothing so as to prevent contact with it during disposal operations. Waste should be spread over the solid waste as thinly as possible and then be promptly covered with additional refuse and earth cover.

Except as modified in the above documents, the site shall be operated in accordance with the terms and conditions of Permit No. 1972-24 dated April 7, 1972.

Very truly yours,

ENVIRONMENTAL PROTECTION AGENCY

C E Clark

C. E. Clark, Manager
Permit Section
Division of Land Pollution Control

TEC:ch

ROCKFORD BLACK TOP CONSTRUCTION CO.

ALL TYPES OF ASPHALT PAVING
GRADING CONTRACTORS
STONE & GRAVEL PRODUCERS
PREMIXED PATCHING

0(BOYLSTON STREET • LOVES PARK, ILL. 61111 • Phone 877-[redacted]

February 10, 1975

Mr. Clark
Supplemental Permit Section
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Re: Winnebago County
Land Pollution Control

Dear Mr. Clark:

I am requesting permission to dispose of the following material:

Landfill: Pagels 1972-24

Source: Automatic Electric

Description: Acid Sludge - see attached sheet

Quantity: 18,000 Gal. per year

Handling: Mix with household refuse

Very truly yours,

CHARLES J. HOWARD, Landfill Manager
Rockford Blacktop Construction Co.

1C-37

Test Number 5-162

MET-Chem Consultants, Inc.
8[illegible] Cedar Street
[illegible]kford, Illinois 61102
8[illegible]5-964-8518

From: Interstate Pollution
1535 - 9th St.
Automatic Electric
Sample I.D. acid
Sample Date 2-7-75

TEST RESULTS

Sample Received 2-7-75

Sample Tested 2-7-75

Acidity

Alkalinity

Aluminum

[illegible] D5

Boron

Cadmium

C[illegible]bon

Chlorine

Chrome 578 ppm

[illegible]OD

Coliforms

Copper 416 ppm

Cyanide

Total

Free

[illegible]o

Flash Point none

[illegible] Point

[illegible]idity Resistance

Iron

Lead

Molybdenum

Nickel

Nitrogen

Oil & Grease

Phosphorus

Salt Spray Res.

Silicon

Silver

Solids Total = 44.3 g/l

Specific Gravity

Sulfur

Surface Tension

Viscosity

Zinc 588 ppm

Other

pH = 0.3

Results submitted by:

[illegible signature]

217-782-6760

March 13, 1975

IN REPLY REFER TO: 20103008
WINNEBAGO COUNTY - Land Pollution Control
New Milford/Rockford Blacktop
Permit No. 1972-24
Supplemental Permit No. 75-80

ILL. E. P. A. STATE OF ILLINOIS

Rockford Blacktop Construction Co.
600 Boylston Street
Loves Park, Illinois 61111

Gentlemen:

Supplemental permit is hereby granted to Rockford Blacktop Construction Co. to accept one time only, 16,000 gallons of plating waste, generated by Midwest Plating, Rockford, Illinois all in accordance with the plans prepared by Charles J. Howard, Rockford Blacktop, dated March 4, 1975 and received by the Agency on March 5, 1975. This supplemental permit is further subject to the following special condition:

> This liquid waste shall be mixed with incoming solid waste at the landfill working face at a rate not to exceed 10 gal./yd^3.

Except as modified in the above documents, the site shall be operated in accordance with the terms and conditions of Permit No. 1972-24 dated April 7, 1972.

Very truly yours,

ENVIRONMENTAL PROTECTION AGENCY

C E Clark

C. E. Clark, Manager
Permit Section
Division of Land Pollution Control

TEC:ds
cc's/-Region N
-File

ROCKFORD BLACK TOP CONSTRUCTION CO.

ALL TYPES OF ASPHALT PAVING
GRADING CONTRACTORS
STONE & GRAVEL PRODUCERS
PREMIXED PATCHING

BOYLSTON STREET • LOVES PARK, ILL. 61111 • Phone 877-[redacted]

March 4, 1975

Mr. Clark
Supplemental Permit Section
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Re: Winnebago County
Land Pollution Control

logged

Dear Mr. Clark:

I am requesting permission to dispose of the following material:

Landfill: Pagels

Source: Midwest Plating

Description: Plating waste

Quantity: 16,000 Gallons — one shot

Handling: Mix with refuse

Very truly yours,

Charles J. Howard

CHARLES J. HOWARD, Landfill Manager
Rockford Blacktop Construction Co.

802 Cedar Street
Rockford, Illinois 61102
815-964-8518

[illegible]
1525-9th St 61108
Sample I.D. Liquid
Sample Date 2-27

TEST RESULTS

Sample Received 2-27-75 Sample Tested 2-27-75

Acidity

Alkalinity

Aluminum
BOD5
Boron

Cadmium
Carbon
Chlorine

Chrome 31 ppm

COD
Coliforms
Copper 650 ppm
Cyanide
Total
Free

DO
Flash Point none
Fire Point
Humidity Resistance
Iron

Lead
Molybdenum
Nickel
Nitrogen

Oil & Grease

Phosphorus

Salt Spray Res.
Silicon

Silver
Solids Total = 13.9%
Specific Gravity
Sulfur
Surface Tension

Viscosity
Zinc 249 ppm
Other
pH - 1.6

Results submitted by:

[signature]

217-782-6760

RECEIVED
MAR 1 ? 1975
ILL. E.P.A. – D.L.P.C.
STATE OF ILLINOIS

March 13, 1975

IN REPLY REFER TO: 20103008
WINNEBAGO COUNTY - Land Pollution Control
New Milford/Rockford Blacktop
Permit No. 1972-24
Supplemental Permit No. 75-81

Rockford Blacktop Construction Co.
600 Boylston Street
Loves Park, Illinois 61111

Gentlemen:

Supplemental permit is hereby granted to Rockford Blacktop Construction Co. to accept one time only, 4000 gallons of plating waste, generated by Midwest Plating, Rockford, Illinois all in accordance with the plans prepared by Rockford Blacktop, dated March 4, 1975 and received by the Agency on March 5, 1975. This supplemental permit is further subject to the following special condition:

This liquid waste shall be mixed with incoming solid waste at the landfill working face at a rate not to exceed 10 gal/yd^3.

Except as modified in the above documents, the site shall be operated in accordance with the terms and conditions of Permit No. 1972-24 dated April 7, 1972.

Very truly yours,

ENVIRONMENTAL PROTECTION AGENCY

C E Clark

C. E. Clark, Manager
Permit Section
Division of Land Pollution Control

TEC:ds
cc's/-Region N
-File

ROCKFORD BLACK TOP CONSTRUCTION CO.

0 BOYLSTON STREET • LOVES PARK, ILL. 61111 • Phone 877-956[illegible]

ALL TYPES OF ASPHALT PAVING
GRADING CONTRACTORS
STONE & GRAVEL PRODUCERS
PREMIXED PATCHING

March 4, 1975

Mr. Clark
Supplemental Permit Section
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Re: Winnebago County
Land Pollution Control

Dear Mr. Clark:

I am requesting permission to dispose of the following material:

Landfill: Pagels

Source: Midwest Plating

Description: Plating waste

Quantity: 4,000 gallons

Handling: Mix with refuse

Very truly yours,

Charles J. Howard

CHARLES J. HOWARD, Landfill Manager
Rockford Blacktop Construction Co.

Test Number ___

MET-Chem Consultants, Inc.
202 Cedar Street
Rockford, Illinois 61102
815-964-6518

From: Interstate Pollution
Midwest Plating

Sample I.D. Sludge
Sample Date 2-27

TEST RESULTS

Sample Received 2-27-75 | Sample Tested 2-27-75

Acidity ___

Alkalinity ___

Aluminum ___
BOD5 ___
Boron ___

Cadmium ___
Carbon ___
Chlorine ___

Chrome 4000 ppm

COD ___
Coliforms ___
Copper 220 ppm
Cyanide ___
Total ___
Free ___

DO ___
Flash Point none
Fire Point ___
Humidity Resistance ___
Iron ___

Lead ___
Molybdenum ___
Nickel ___
Nitrogen ___

Oil & Grease ___

Phosphorus ___

Salt Spray Res. ___
Silicon ___

Silver ___
Solids Total = 18.0 %
Specific Gravity ___
Sulfur ___
Surface Tension ___

Viscosity ___
Zinc 1140 ppm
Other ___
pH = 8.3

Results submitted by:

[signature]

EXHIBIT 3

TO

AFFIDAVIT OF CHARLES J. HOWARD

Division of Land Pollution Control
Permit Section
2200 Churchill Road
Springfield, Illinois 62706

Issued 6/4/75
Expires 6/4/76
Permit No. 75-239
Approved [illegible]

...ation for a Supplemental Permit for the Disposal of Special and/or Hazardous Wastes at an IEPA Permitted Solid Waste Management Site

I. GENERAL INFORMATION

A. Name of Applicant: Rockford Blacktop Construction Co.
Address: 600 Boylston Street, Loves Park, Ill. 61111
Telephone: 815-877-9561

B. Name of SWM Site: Winnebago (County) (City or Township) Pagel (Site)
I.E.P.A. Operation Permit No. 1972-74
Site Inventory No. 20180301

C. Name of Special Waste Generator: Acme Resin
Address: Pines Road, Box 130
Telephone: Oregon, Ill. 61061

D. Name of Special Waste Hauler: Interstate Pollution
Address: 1525 9th St., Rockford, Ill.
Telephone: 815-964-2058

CHARACTERISTICS OF WASTE

A. Quantity 1000 gallons (cubic yards or gallons) per month (day, week, month)

for monthly (one time, week, month, etc.)

RECEIVE[D]
JUN 3 1975
ILL. E.P.A. - D.L.[P.C.]
STATE OF ILLINO[IS]

B. Quality

1. Name of Waste: Phenol IN WATER BASE

2. Name the process and/or type of industry producing the waste: Foundry Sand Producers, OVEN WET SCRUBBER

3. An analysis of the chemical and physical characteristics of the waste must be determined by a qualified lab and be attached to this applicatio[n]. Does the special waste contain any hazardous chemicals? Phenols

4. All hazards (health, safety, and/or fire) and/or nuisance problems associated with the waste must be designated and necessary safety and handling precautions delineated. Specify available communications and assistance in case of emergency or fire. Pagels phone 815-876-7375

New Milford Fire Protection District 874-2456

PHYSICAL CONTACT & INHALATION OF THE WASTE FUMES SHOULD AVOIDED.

APPENDIX D

Letter Report from Warzyn Engineering, Inc.,
April 28, 1980; and IEPA Memorandum of
August 14, 1981 Documenting Acme
Solvents as Probable Source of
Well Contamination East of Pagel's

WARZYN
ENGINEERING INC

Consulting Engineers • Civil • Structural • Geotechnical • Materials Testing • Soil Borings • Surveying

1409 EMIL STREET, P.O. BOX 9538, MADISON, WIS 53715 • TEL (608) 257-4848

(A)

~~DAW~~
~~HAK~~
~~SJU~~
FILE

April 28, 1980
C 9078

Mr. Chuck Howard
c/o Rockford Blacktop Construction Company
600 Boylston Street
Loves Park, IL 61111

Re: Hydrogeologic Investigation
Pagel Pit Landfill

Dear Mr. Howard:

This letter and the accompanying drawings present the results of the hydrogeologic investigation in the vicinity of Pagel Pit Landfill. Recently, two private wells (Lyford and Baxter) located along Lindenwood Road have been shown to be contaminated. The purpose of this investigation was to determine whether the Pagel Pit Landfill is contributing to the degradation of water quality at these wells. The investigation included the collection and analytical analysis of water quality samples, a review of the historical water quality records of wells in the vicinity of the landfill, and the analysis of recently measured water levels.

The direction of groundwater movement beneath a source of contamination dictates the potential migration direction of the contaminant within a groundwater flow system. As the accompanying water table map (Drawing C 9078-A1) indicates, groundwater flow in the vicinity of the landfill is from east to west, with shallow groundwater probably discharging into Killbuck Creek. The Lyford and Baxter wells are upgradient, or upstream, from the landfill with Monitoring Wells PP4 and PP6 being alongside, or marginally downgradient from the landfill.

The results of the water quality analyses of samples obtained on March 7, 1980 are attached. The data indicates that the source of contamination is probably to the east of the Lyford and Baxter residences. The two on-site monitoring wells, PP4 and PP6, displayed the lowest concentrations of parameters analyzed for, whereas the Lyford and Baxter wells displayed the highest concentrations of these parameters. The

Blacktop House and Scale-House wells were between these two extremes. The attached isoconcentration map of conductivity measurements illustrates the trend of decreasing concentrations to the west. Total alkalinity, total hardness, and nitrate concentrations at the Lyford and Baxter homes are generally two times higher than at PP4 and PP6 and display the same areal trends as conductivity. Nitrate concentrations at the Blacktop House, Lyford house, and Baxter house wells exceed the Interim Drinking Water Standard of 10 mg/l established by the United States Environmental Protection Agency. A comparison of the historical water quality data for PP4 and PP6 (starting on 1972) and the recent data shows no significant change in water quality at those two wells since 1972.

An abandoned solvent storage site, located approximately 2000 feet east of Lindenwood Road, appears to be the likely source of contamination at the Lyford and Baxter wells. Based on a visual inspection of the site area and reports by landfill personnel, various waste materials including many buried barrels, were dumped in an abandoned limestone quarry. The potential for leachings from the waste to migrate down to the water table and contaminate groundwater in a downgradient direction is high in what is presumed to be a fractured limestone environment.

In summary, the water level and water quality data indicate the Pagel Pit Landfill is not the source of contamination at the Lyford and Baxter wells. It cannot be shown that no groundwater impact has occurred at the landfill since no directly downgradient wells exist. Currently available information indicates the source of contamination of the wells in question may be the abandoned solvent storage site. Additional documentation would be necessary to conclusively show the abandoned solvent storage site is the source of this contamination or to document an alternate source. Due to the unknown nature of waste material disposed of at the suspect site, we urge caution in using the affected water supplies and recommend the homeowners be so notified.

If you have any questions or comments regarding the above information, please do not hesitate to contact us.

Respectfully submitted,

WARZYN ENGINEERING INC.

Steven G. Wittmann
Project Manager

Daniel R. Viste
Chief Hydrogeological Section

SGW/DRV/dmf
Encl: Water Table Map, C 9078-A1
Isoconcentration Map-Conductivity, C 9078 A2
Analytical Laboratory Results, March 7, 1980

WARZYN

WARZYN

ENGINEERING INC

ANALYTICAL LABORATORY RESULTS

Project Rockford Blacktop

Location Rockford, Illinois

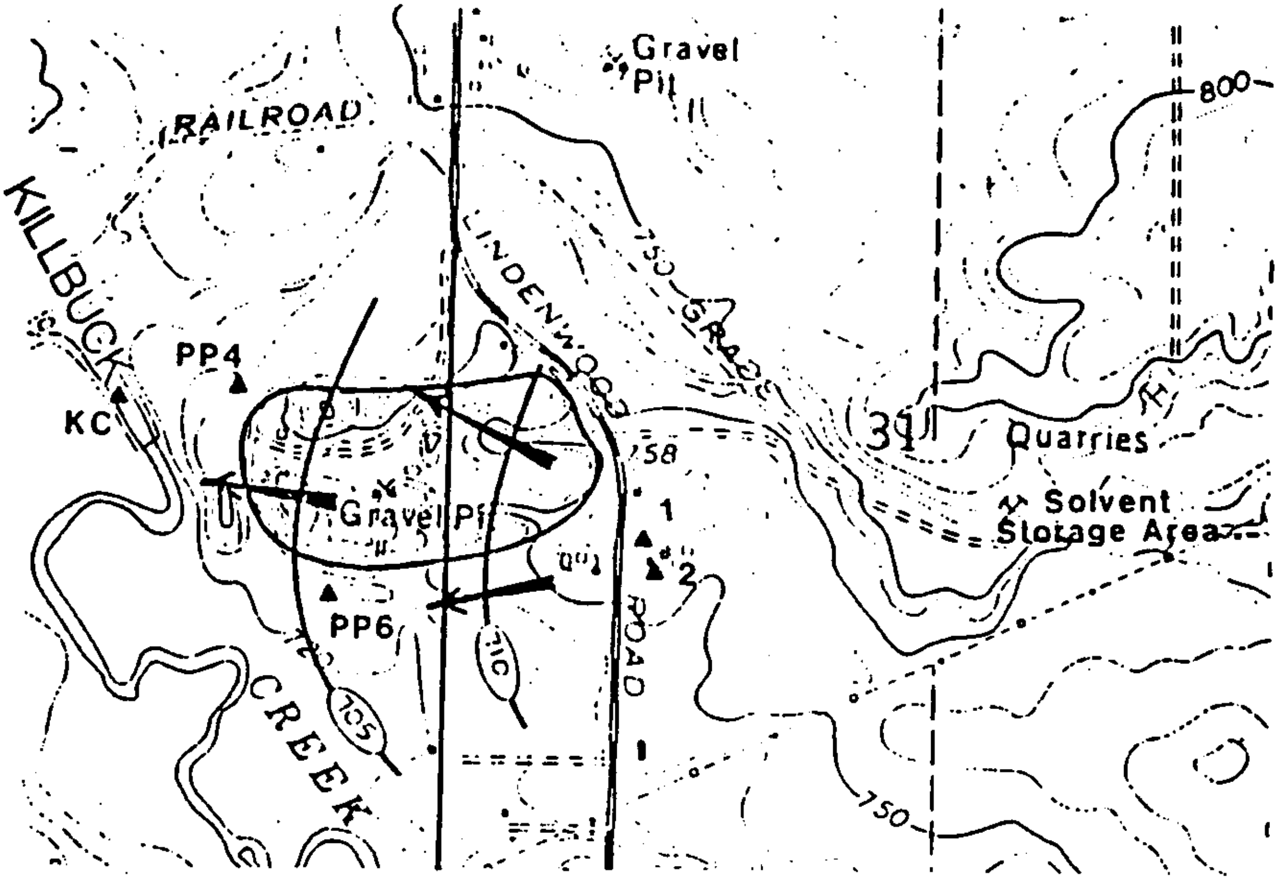
Date Received: 3/7/80
Project No: C 9078
Sheet 1 of 1
Ckd JC App'd
Date Issued: 3/13/80

1409 EMIL STREET · P.O. BOX 9538, MADISON, WIS. 53715 · TEL. (608) 257-4848

Sample No.	pH Units	Conductivity umhos/cm	* Total Alkalinity	Chemical Oxygen Demand	Chloride	Total Hardness	Nitrate Nitrogen	Sulfate
Baxter Well	6.55	1490	708	12	26	900	13	72
Blacktop House	6.80	990	426	<10	25	540	11	47
Lyford Well	6.75	1310	464	21	50	670	28	65
Scale House & MP1	7.10	745	348	<10	12	420	4	32
Pagel Pit #PP4	7.30	655	280	12	21	330	4	18
Pagel Pit #PP6	7.40	640	252	<10	13	350	7	43

* Test run 3 days after sample collection

All parameters are mg/l unless otherwise stated.



WATER LEVEL	WELL
703.61'	PP4
705.64'	PP6
714.49'	#1 BAXTER
714.83'	#2 LAFORD
702.20'	KC - KILLBUCK CREEK

LEGEND

LANDFILL AREA

WATER TABLE CONTOUR

GROUNDWATER FLOW DIRECTION

WELL LOCATION

north

SCALE: 1" = 1000'

WARZYN ENGINEERING INC

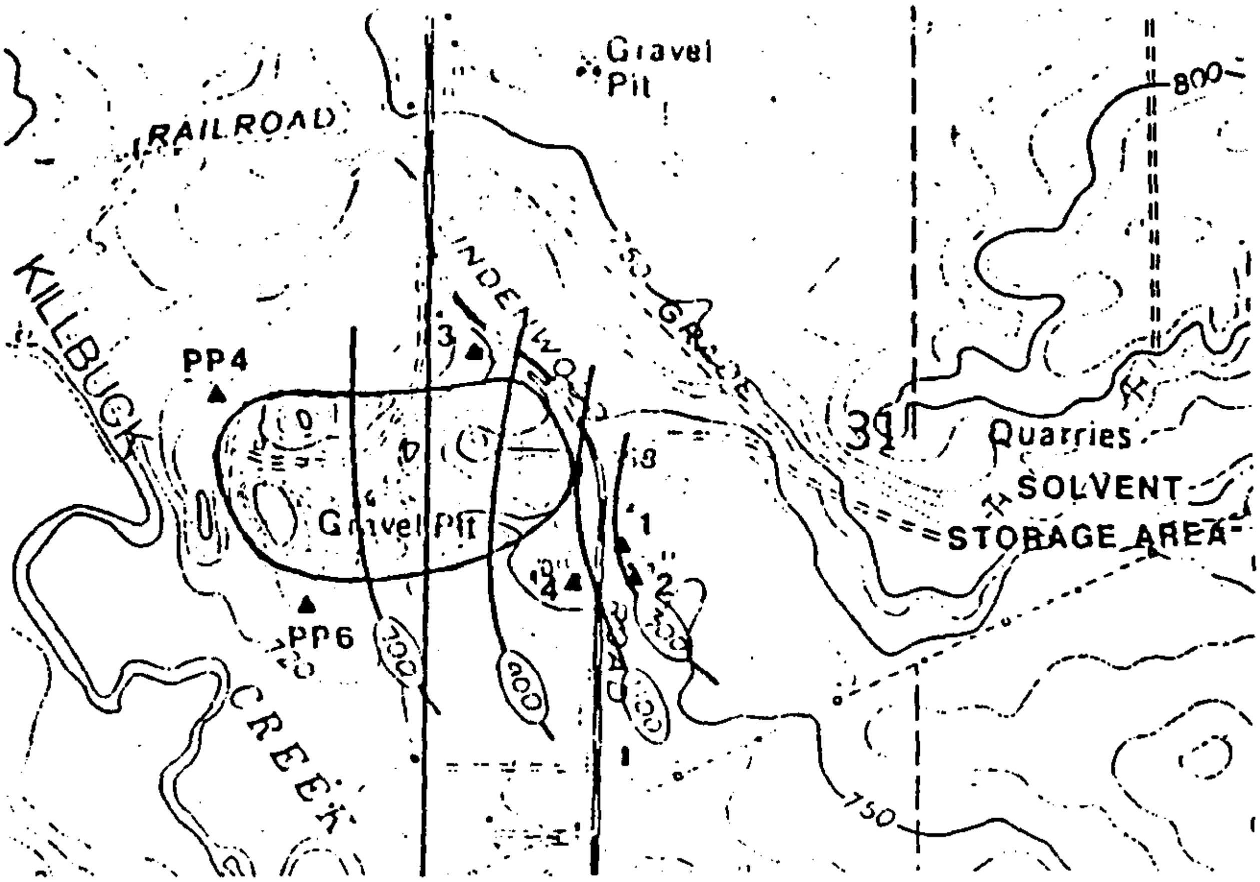
WATER TABLE MAP 3-20-80

Pagel Pit Landfill

Rockford Blacktop Construction Company

Winnebago County, Illinois

DWN	CHKD	APPD	DATE	
[illegible]	[illegible]	Daniel [illegible]	4-28-80	[illegible] A1



CONDUCTIVITY*	WELL
655	PP4
640	PP6
1490	#1 [illegible]
1310	#2 [illegible]
745	#3 [illegible]
990	#4 [illegible]

LEGEND

LANDFILL AREA

▲1 WELL LOCATION

—(900)— LINE OF EQUAL CONDUCTIVITY CONCENTRATION

north

SCALE: 1"=1000'

*CONDUCTIVITY [illegible]

WARZYN ENGINEERING INC

ISOCONCENTRATION MAP-CONDUCTIVITY

Pagel Pit Landfill

Rockford Blacktop Construction Company

Winnebago County, Illinois

DWN [illegible]	CHKD [illegible]	APPD David R. [illegible]	DATE 4-28-80	C9018-A2

E

APPENDIX E

Illinois Environmental Protection Agency Monitoring Data Sheet Showing Presence of Arsenic and Other Substances at the Acme Solvents Site

VEL

ENVIRONMENTAL PROTECTION AGENCY STATE OF ILLINOIS

DIVISION OF LAND/NOISE POLLUTION CONTROL ANALYSIS FORM

Key for Determining Type of Monitoring Point

(S) Surface Water	(G) Ground Water	(L) Leachate	(X) Special
(1) Upstream	(1) Monitor Well	(1) Flow or seep	(1) Soil
(2) Mid-site	(2) Private well	(2) Pond	(2) Waste
(3) Downstream	(3) Spring	(3) Collection System	(3) Other
(4) Run-off	(4) Lysimeter		
(5) Impounded			

IEPA - Old Private Well - East

Name (Private Well, Stream, Spring, Impounded Water only)

L P C S M 0 1 0 (1) (8) SITE INVENTORY NUMBER (9) 2 0 1 0 2 0 0 1 (16)

MONITOR POINT NUMBER (17) G103 (20) DATE COLLECTED (21) 020282 (26)

Winnebago Co. - LPC REGION R (27)

Morristown / Acme Solvent

(Location) (Responsible Party)

Legal (1); Illegal (2); Indicate One: 2 (28) Board Order (X) X (29)

Time Collected 9:15 a.m./p.m. Unable to collect sample (X) (30)

Stick-up (31) 0.5 (33) ft. Depth to water (from T.O.C.) (34) 31.9 (36) ft.

Sample temp. (37) 50 °F (39) Background (X). . . . (40)

Ground water sampled by (Indicate one): (1) Bailing; (2) Pumping; (3) Other (Specify) ______ 1 (41)

Sample Appearance: No odor. Clear. TD = 72.4'. Filtered in office.

Collector comments: Fmod. recharge. Bailed 1 volume at 12:35 PM on 2-1-82.

K. Barda — DLPC

Collected by — Div. or Company

K. Barda — DLPC

Transported by — Div. or Company

LAB USE ONLY

Lab No. C003664

Date Rec'd 2-3-82

Rec'd by R. Mulli Time 10:30 a.m./p.m.

Sample temp. acceptable YES NO

Sample properly preserved YES NO

Date completed

Date forwarded MAR -9 1982

Daugherty

Supervisor Signature

Name Environmental Protection Agency

Address Division of Laboratory Services

of Lab 2121 W. Taylor Street

Chicago, Illinois 60612

LPCSM020

Lab Comments:

(27) Hg < 0.00005 (36)

(37) ------ (76)

(27) ------ (36)

(37) ------ (66)

(37) ------ (76)

Private Lab (X)

IEPA Lab (X) X (77)

LPCSM010

		PARAMETERS*	PPM
27	X	Alkalinity[1]	530.xx
31	X	Ammonia as N	0.47
37	X	Arsenic As	0.00
44	X	Barium Ba	Interference
49		BOD-5	.xx
53	X	Boron B	0.3x
58	X	Cadmium Cd	0.0
64	X	Calcium Ca	105.8x
69	X	COD	6.xx
73	X	Chloride Cl	19.xx

LPCSM040

27	X	Chromium Cr (tot)	0.00
33	X	Chromium Cr^{+6}	0.0
39	X	Copper Cu	0.03
45	X	Cyanide[2] CN	0.00
52		Fecal Coli	.xx
56	X	Fluoride F	0.2
61	X	Hardness $CaCO_3$	480.xx
65	X	Iron Fe	0.7x
70	X	Lead Pb	0.0

LPCSM050

27	X	Magnesium Mg	50.xx
32	X	Manganese Mn	0.69
38	X	Mercury Hg	—
46	X	Nickel Ni	0.0x
51	X	Nitrate-nitrite N	0.1x
56		Oil and Grease	.xx
60	X	pH (Units)	xx 8.1xx
63	X	Phenolics	0.006
70	X	Phosphorus P	0.01x
76	X	Potassium K	0.9xx

LPCSM060

27	X	R.O.E. (180°C)	500.xx
31	X	Selenium Se	0.00
38	X	Silver Ag	0.00x
44	X	Sodium Na	6.5x
49	X	SC (umhos/cm)	497 xxx
53	X	Sulfate SO_4	32.xx
58	X	Zinc Zn	0.2x
63	X	Sulfides	0.00

*Analyses are to be performed on unfiltered samples. #Values exceeding no. of places shown are reported in the lab comments section; tests requested but not run should also be explained in the lab comments section.

[1] Alkalinity is to be determined as ppm of $CaCO_3$ at pH 4.5.

[2] Cyanide is to be reported as free cyanide

H.W.

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APPENDIX F

"Migration and Degradation Patterns of Volatile Organic Compounds"

MIGRATION AND DEGRADATION PATTERNS
OF VOLATILE ORGANIC COMPOUNDS

ABSTRACT

MIGRATION AND DEGRADATION PATTERNS OF VOLATILE ORGANIC COMPOUNDS

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The mobility and persistence of volatile, chlorinated priority pollutants has been documented at sites across the country. Examples of commonly used solvents include 1,1,1-trichloroethane, trichloroethene, tetrachloroethene, and methylene chloride. At some facilities, other volatile compounds have been detected in significant concentrations, which were never handled or disposed at these same facilities. Some of these other compounds include dichloroethanes, dichloroethenes, chloroethane, and vinyl chloride. Based on recent research (Wood et al., 1981; Parson et al., 1984), these less commonly used solvents can be present as a result of anaerobic degradation of major contaminants (commonly used solvents) within the groundwater system.

This paper presents data to help clarify under what conditions one may anticipate finding degradation products and discusses their distribution trends. The data presented was compiled from studies conducted at solvent recovery facilities, solid/hazardous waste landfills and solvent contamination near an industrial facility. After review of data from these sites, the following conclusions were drawn:

1. When degradation occurs, the parent solvent compounds are at highest concentrations near the source. With distance from the source, increasing proportions of degradation products are present.

2. Degradation products are most frequently found near a source containing high concentrations of other organic compounds. These other organics may consist of organic material from a landfill, other non-chlorinated solvents, or high organic content in the soil. These organic compounds appear to increase the rate of parent solvent degradation.

3. More complete degradation may occur in the upper portion of the zone of saturation than with depth in the aquifer.

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4. Due to the high specific gravity of chlorinated compounds, they will sink through the aquifer when in excess of their solubility until they are adsorbed, dissolved, and/or reach an impermeable layer. Dissolved constituents move with the groundwater as dictated by the hydrogeology of an area.

5. Standard analytical protocols for measurement of volatile organic priority pollutants by GC/MS do not distinguish between a highly-toxic priority pollutant and a significantly less hazardous non-priority pollutant degradation product, which is the dominant degradation contaminant present at these sites.

This paper will demonstrate the application of this information to design of specific site investigation programs. Recommendations are proposed for presentation and analysis of data generated during solvent contamination investigations.

* First time presentation of data.

PVC/blc/dkp
[dkp-194-8]

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MIGRATION AND DEGRADATION PATTERNS OF VOLATILE ORGANIC COMPOUNDS

INTRODUCTION

Volatile organic priority pollutants have been detected in groundwater at sites across the country. These compounds are widely used as solvents and are considered mobile and persistent in the environment. Improved analytical methods using gas chromotography and/or mass spectroscopy now allow detection of these synthetic organics to extremely low levels. The presence of the synthetic organics in groundwater coupled with our ability to detect them has resulted in increasing numbers of contamination investigations for these compounds.

Biodegradation is not typically an integral part of todays groundwater investigations.There is considerable controversy regarding whether degradation is an important factor in determining the fate of the chlorinated volatile organic priority pollutant. Increasing evidence indicates chlorinated solvents can be degraded in an anaerobic environment by reductive dehalogenation. The sequential removal of chlorine atoms from halogenated 1 and 2 carbon aliphatic compounds results in formation of other volatile, chlorinated priority pollutants which can be detected during investigations of solvent contamination.

This paper presents data from a variety of sites having documented contamination by chlorinated solvents. This data is examined for patterns predicted by research which indicate reductive dehalogenation may be a primary mechanism for breakdown under specific site conditions. It is reported this process occurs when the oxidation/reduction potential is less than 0.35V.

Research data indicates chlorinated solvents have varying rates of breakdown. Data was therefore evaluated for a dominance of compounds which show longer half-lives, including 1,2-dichloroethenes and vinyl chloride.

BACKGROUND INFORMATION

For purposes of this data evaluation, selected compounds were designated as "parent" compounds based on their widespread use and/or known presence at these specific sites. These compounds include methylene chloride, 1,1,1-trichloroethane, trichlorethene and tetrachloroethene.

Breakdown products are designated as compounds which would result from reductive dehalogenation of these parent compounds and include dichloroethanes, chloroethane, dichloroethenes and vinyl chloride. For purposes of this evaluation, methylene chloride is disregarded, since it is a commonly used solvent, potential degradation product, and common laboratory contaminant. Emphasis is placed therefore on the ethene and ethane series. The breakdown series for the chlorinated ethenes and ethanes is shown below:

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ANAEROBIC BREAKDOWN SEQUENCE VIA REDUCTIVE DEHALOGENATION

Chlorinated Ethenes

Tetrachloroethene(1) $\xrightarrow{\uparrow Cl}$ Trichlorethene(1) $\xrightarrow{\uparrow Cl}$ cis-1,2(2) / trans-1,2(2) / 1,1-(1) dichloroethene $\xrightarrow{\uparrow Cl}$ Vinyl Chloride(2)

Chlorinated Ethanes

1,1,1-Trichloroethane(2) $\xrightarrow{\uparrow Cl}$ 1,1-dichloroethane(1) $\xrightarrow{\uparrow Cl}$ chloroethane(1)

(1) Research indicates substantial degradation.
(2) Research indicates degradation is slow.

In work performed at the Florida International University by Wood and Parsons, biodegradation of either trichloroethene or tetrachloroethene produced higher concentrations of cis- 1,2-dichlorethene as compared to the trans-isomer.

Trans-1,2-Dichloroethene is a priority pollutant and has a somewhat lower criteria for drinking water (272 ppb) as compared to the cis-isomer (400 ppb).* The Environmental Protection Agency's rationale for selection of the trans-isomer as the priority pollutant was based on the availability of the analytical standard.

DATA PRESENTATION

In our first attempts to correlate the ethene breakdown series with data from our sites, it became apparent that the dominant dichloroethene compound detected is trans-1,2-dichlorethene. The cis-isomer is not a priority pollutant and therefore not mentioned in the methods for analysis of the volatile organic priority pollutants using Method 601 or Method 624.

* Department of Health and Social Services, Interim Health Advisory Opinions (January 24, 1984).

These methods recommend the use of a column composed of 1% SP 1000 on carbopack B. The isomer pair cannot be separated using the above column. In addition, since they have identical mass spectra, the isomer pair will not be differentiated by mass spectrometry and will subsequently be identified as the trans-isomer.

The above was verified by the submittal of a standard mix containing both the cis- and trans-isomers to a prominent midwestern laboratory. Analysis by Method 624 found only the trans-isomer, but the quantitated result equalled the known total of the isomer pair.

The Michigan Department of Health has the capability of separating the cis- and trans-isomers and, in a current investigation, has determined that the major contaminant at a site is not trans-1,2-dichloroethene as found by an EPA contract laboratory, but is in fact the cis-isomer. They have indicated that frequently they find the cis-isomer and, if concentrations are high, they occasionally find traces of the trans-isomer.

Based on this information, we conclude that much of what is typically reported as the trans-isomer, which is a priority pollutant, is in fact cis-1,2-dichloroethene. In the subsequent evaluations, we will refer to these compounds as 1,2-dichlorethenes.

A. Landfills

Landfills which dispose of municipal waste provide an anaerobic environment where substantial breakdown of compounds occurs. At sites which have also accepted waste products containing solvents, a number of volatile organic priority pollutants can be detected in the leachate. Table 1 summarizes the analysis of five leachate samples from Site #1 which accepted both municipal and industrial wastes. The site also received significant quantities of hazardous and nonhazardous liquid wastes. Based on site records of waste accepted, there is a dominance of "breakdown products" at this site.

TABLE 1

LANDFILL LEACHATE
SITE #1

	Leachate Sample Number†				
	1	2	3	4	5
Chlorinated Ethanes					
[1] Trichlorethanes	ND	68	ND	ND	ND
[2] 1,1-Dichloroethane	1,500	240	130	11	13
1,2-Dichloroethane	ND	12	21	ND	ND
Chloroethane	ND	21	18	160	ND
Chlorinated Ethanes					
[1] Tetrachloroethene	ND	13	ND	ND	ND
Trichloroethene	ND	100	62	ND	ND
[2] 1,2-Dichloroethenes	3,200	990	950	150	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND
Vinyl Chloride	ND	120	59	100	ND
Other Volatile Priority Pollutants					
Methylene Chloride	5,300	120	770	ND	14
Toluene	2,000	410	660	460	58
Benzene	ND	30	37	110	16
Ethylbenzene	ND	93	64	140	68
1,2-Dichloropropane	ND	18	37	ND	ND

All Concentrations are in ug/l.

[1] - Parent Compounds
[2] - Breakdown Products
ND- <10 ug/l

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Table 2 summarizes the percent of breakdown products detected in groundwater at two other sites where volatile organic contamination has migrated off-site. Site #2 is a small municipal landfill in a sand and gravel environment and Site #3 is a large site in a clay environment which has accepted waste similar to Site #1. At these sites, we have also documented a dominance of the breakdown products in groundwater downgradient from the waste disposal boundaries.

TABLE 2

BREAKDOWN PRODUCTS(1) PRESENT IN CONTAMINATED GROUNDWATER NEAR DISPOSAL FACILITIES

	Site #2 Small Municipal Facility	Site #3 Large Codisposal Facility
Number of Samples from Wells showing Solvent Contamination	10	8
Number of Samples with <50% Breakdown Products	2	0
Number of Samples with 50-75% Breakdown Products	3	0
Number of Samples with 75-100% Breakdown Products	5	8

(1) Breakdown defined as monochloro- and dichloro- ethanes and ethenes compared to total chlorinated ethanes and ethenes.

The purpose of presenting data from landfills is to demonstrate that in an anaerobic, high-organic matrix, one is likely to find compounds which are a result of reductive dehalogenation. It is unlikely at these sites that these compounds were the dominant disposal compounds based on site records, general production and common use. Of particular interest is the fact that all eight of the leachate samples from the large co-disposal facility were comprised of greater than 75% breakdown products.

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B. Solvent Recovery Facilities

The following is a summary of geologic and hydrologic characteristics at two solvent recovery facilities.

	Site 1	Site 2
Location	Connecticut	Wisconsin
Date of Investigation	1980	1983
Geology	Alluvial sands and gravel in relatively impermeable bedrock valley	Thick, sandy glacial till deposits overlying limestone bedrock
Hydrology	Shallow groundwater, <10', alluvial sands constitute primary municipal aquifer	Till supports only minimal groundwater withdrawal, permeability approximately 10^{-4} to 10^{-5} cm/sec. Limestone is aquifer in the area.

Tables 3 and 4 summarize analytical data from the above sites. Both sites handled chlorinated and nonchlorinated solvents. High concentrations of both the chlorinated and nonchlorinated compounds were present near the handling areas on-site. The off-site contamination showed a dominance of the chlorinated compounds. Nonchlorinated compounds detected were priority pollutants. In cases where analyses were performed, the presence of compounds like toluene and benzene were indicative of a much higher concentration of other nonpriority pollutant hydrocarbons.

At the Wisconsin site, dichlorethanes, dichlorethenes and vinyl chloride were detected in significant concentrations in the groundwater. These compounds were not handled at the facility, and this is supported by records of routine gas chromatographic analyses at the recycling facility. Further evaluation failed to indicate the presence of other possible sources of the breakdown products. Information was not available to evaluate this question at the Connecticut site.

An evaluation was then performed to assess whether data from these facilities show patterns which would be a result of anaerobic degradation. The evaluation includes an analysis of the percentage of breakdown products measured at the source and at a downgradient location.

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TABLE 3

SOLVENT RECOVERY OPERATIONS

SUMMARY OF VOLATILE ORGANIC PRIORITY POLLUTANTS DETECTED AT ON-SITE AND DOWNGRADIENT PIEZOMETERS

CONNECTICUT

	On-Site		250' Downgradient	
	Water Table	At Depth	Water Table	At Depth
Chlorinated Ethanes				
[1] 1,1,1-Trichloroethane	ND	3,700	260	ND
[2] 1,1-Dichloroethane	8,300	3,000	2,500	ND
Chlorinated Ethenes				
[1] Tetrachloroethene	2,900	ND	34	ND
Trichloroethene	39,000	330	ND	ND
[2] 1,2-Dichloroethenes	30,000	2,700	ND	4,300
1,1-Dichloroethene	ND	ND	ND	ND
Vinyl chloride	ND	200	ND	2,700
Other Solvents Detected				
Methylene Chloride	100,000	7,000	25	3,900
Ethylbenzene	12,000	440	ND	3,700
Toluene	34,000	5,100	ND	7,600

All Concentrations are in ug/l.

1 - Parent Compounds
2 - Breakdown Products
ND- <10 ug/l

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TABLE 4

SOLVENT RECOVERY OPERATIONS

SUMMARY OF VOLATILE ORGANIC PRIORITY POLLUTANTS DETECTED AT ON-SITE AND DOWNGRADIENT PIEZOMETERS

WISCONSIN

	On-Site		250' Downgradient	
	Water Table	Depth	Water Table	Depth
Chlorinated Ethanes				
[1] 1,1,2,2-Tetrachloroethane	19,000	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	60
1,1,1-Trichloroethane	22,000	270,000	ND	20,000
[2] 1,2-Dichloroethane	ND	ND	ND	230
1,1-Dichloroethane	ND	6,200	ND	5,100
Chloroethane	ND	ND	ND	90
Chlorinated Ethenes				
[1] Tetrachloroethene	ND	22,000	ND	610
Trichloroethene	63,000	250,000	ND	1,000
[2] 1,2-Dichloroethenes	30,000	8,700	ND	47,000
1,1-Dichloroethene	ND	ND	ND	720
Vinyl Chloride	ND	ND	ND	210
Other Solvents Detected				
Methylene Chloride	230,000	170,000	ND	20,000
Benzene	12,000	ND	ND	20
Ethylbenzene	28,000	9,200	ND	630
Toluene	100,000	42,000	ND	4,100

All Concentrations are in ug/l.

1 - Parent Compounds
2 - Breakdown Products
ND- <10 ug/l

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[dkp-194-7]

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To illustrate trends, data has been summarized showing results of the priority pollutant analyses for a water table well and piezometer located on-site showing the highest concentrations, as well as a down-gradient water table well and piezometer. At both of the sites, primarily horizontal hydraulic gradients were observed such that higher concentrations of contaminants were anticipated at the water table wells.

Figure 1 shows the total volatile organic concentrations detected at the above described well locations for both sites and the percentage of breakdown products as compared to the sum of the chlorinated ethanes and ethenes.

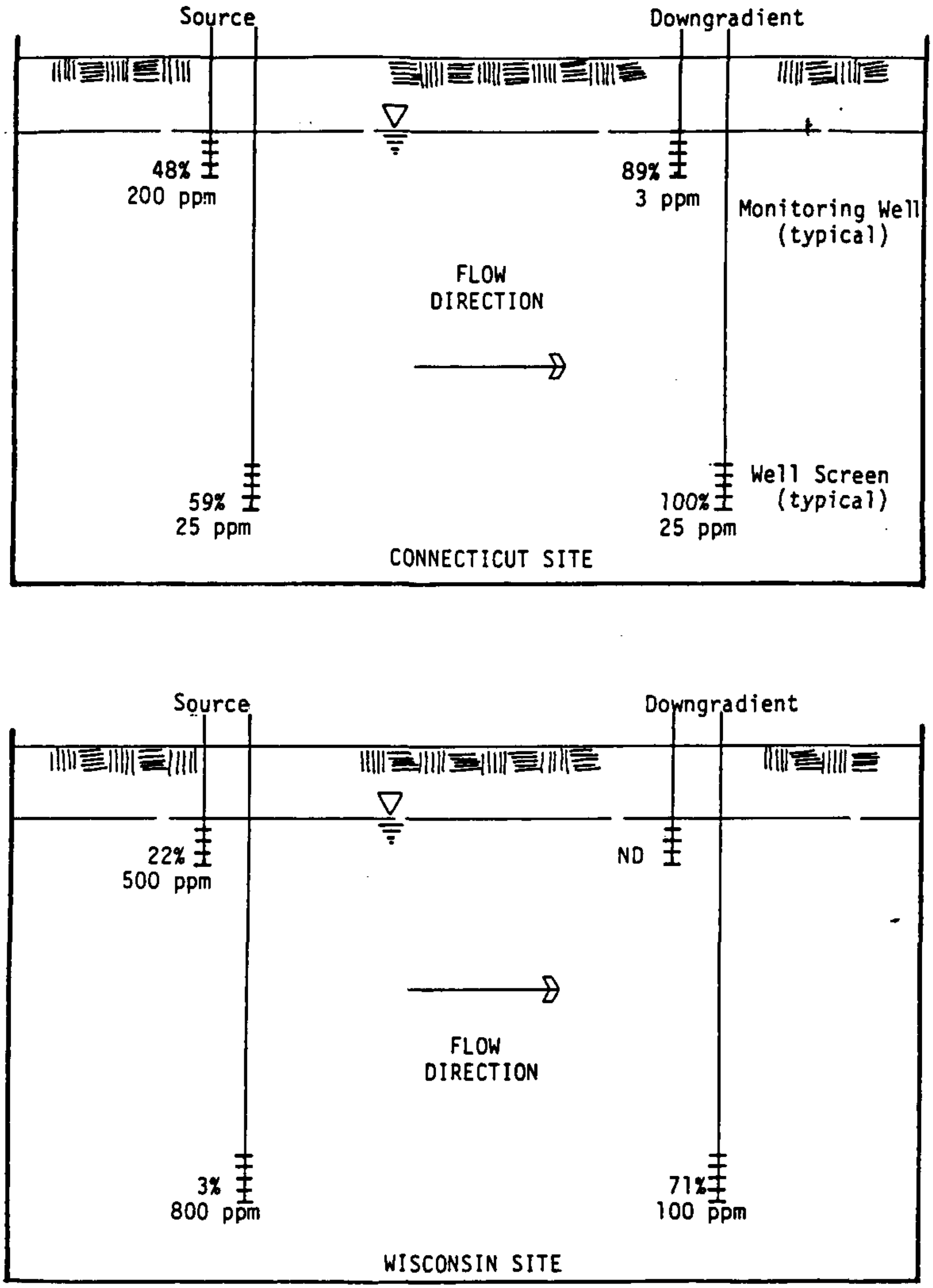
Both of the sites exhibited high levels of chlorinated organic contamination at the source. Nonchlorinated organics were also present at the sources in high concentrations, providing a nonchlorinated carbon source. These nonchlorinated organic compounds were present in highest concentrations at the water table. At the Wisconsin site, a floating layer of fuel oil type material was detected at one well.

With distance downgradient from the source, the contaminants were detected at greater concentrations with depth even though groundwater flow was near horizontal. There are various explanations for this phenomenon, including changing groundwater flow patterns, recharge, or impermeable barriers which may have hampered migration of contaminants to the water table wells. These parameters will be evaluated further with additional hydrogeologic study, where funding is available.

Other explanations include density effects, volatilization and selective degradation. It is well documented that chlorinated compounds will sink in the aquifer at the source when in excess of the solubility of water. For subsequent density effects to be apparent in the contaminated groundwater where concentrations are lower, the overall density of that solution must be greater than that of background water quality. Preliminary calculations indicate that at the concentrations measured at the sites, the density difference would not be sufficient to account for sinking of the contaminated groundwater plumes.

The EPA has indicated that a primary environmental fate for these compounds in aquatic systems would be volatilization. Although it is recognized that some volatilization will occur from the water table, upward diffusion through the groundwater to reach the water table surface and subsequent diffusion through the soils would significantly reduce the rate of loss of these compounds via that mechanism. In drier climates, this may account for a more substantial loss from the water table.

FIGURE 1
BREAKDOWN PATTERNS



% Values = % Breakdown Products
ppm Values = Total of all Volatile Priority Pollutants

Selective degradation is presented as another possible explanation for preferential loss of the constituents at the water table wells. It is understood that biodegradation of chlorinated compounds may be related to presence of other carbon sources by co-metabolism. Solvent recovery operations can provide a nonchlorinated carbon source which tends to accumulate near the water table surface. These compounds are typically not detected with distance from the source, due to rapid breakdown, and may be responsible for preferential loss of the chlorinated compounds from the more shallow zone of the aquifer. The breakdown of the chlorinated compounds can occur rapidly in the presence of a nonchlorinated carbon source which promotes rapid co-metabolism to dehalogenate the chlorinated compounds. The data suggests that degradation continues to occur at depth, perhaps at a slower rate.

C. Industrial Site

For purposes of contrast with sites which have high levels of contamination, and a substantial carbon source, we have presented data from an industrial site having primarily sandy soils, shallow groundwater and little or no detectable nonchlorinated organic priority pollutants. Table 5 summarizes data near an industrial facility which was monitored due to contamination of a city well with chlorinated compounds.

Three major contrasts with data from the solvent recovery facilities are noted:

1. Overall contaminant concentrations detected are lower and all compounds are chlorinated.

2. A dominance of the parent compounds exists.

3. The plume was detected in highest concentrations at the water table wells. The lack of a significant carbon source to promote degradation can account for the minimal breakdown occurring at the industrial site.

TABLE 5

INDUSTRIAL SITE SOLVENT CONTAMINATION SUMMARY

Well	1,1,1-Trichloroethane	Trichloroethene	1,1-Dichloroethene
1	ND	81	ND
2	13,800	2,040	250
3	2,660	410	ND
4	7	1	ND
5	8	2	ND
6	ND	68	ND
7	10	12	ND

All Concentrations are in ug/l.
ND - <1 ug/l

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SUMMARY

Parameters which would help to determine biodegradation activity are typically not incorporated into standard hydrogeologic investigations. A better understanding of the role of degradation could be obtained through a more comprehensive investigative program including biological assessment as well as the standard groundwater flow and chemistry analyses.

Data from our investigations suggest that if a site has a substantial carbon source, anaerobic degradation will occur resulting in the development of dichloro- and or monochloro- ethane and ethene compounds. The presence of these compounds follows the predictions in the literature regarding the degradability of these compounds. In addition, the research indicates that the cis-isomer of 1,2-dichloroethene is formed during degradation and is more typically present in these investigations than the priority pollutant trans-isomer.

A floating organic layer near a contamination site may enhance the rate of degradation near the water table as the chlorinated compounds would more readily be co-metabolized in that zone of the aquifer.

RECOMMENDATIONS

At sites where degradation is indicated, additional measurements should be made to better understand the potential role and controlling mechanisms of biodegradation: This would include measurement of the overall organic content in the indicated water or soil, measurements of oxidation reduction potential (Eh) and density measurements of the contaminated groundwater. During data interpretation, one can evaluate the presence of breakdown products and the pattern of their occurence in relation to the parent compounds. It is also recommended that one report "1,2-dichloroethenes" without specifying the specific cis- or trans-isomer, unless that specific distinction can be made by the analytical laboratory.

It is hoped that increased awareness of the conditions under which maximum degradation can occur will improve the approach and substantially increase the conclusions which can be drawn from groundwater contamination investigations.

PVC/dkp/cwl
[dkp-194-7]

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PVC/cwl/dkp
[dkp-194-9]

APPENDIX G

"Anaerobic Transformation, Transport and Removal of Volatile Chlorinated Organics in Groundwater"

ANAEROBIC TRANSFORMATION, TRANSPORT AND REMOVAL OF VOLATILE CHLORINATED ORGANICS IN GROUNDWATER

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INTRODUCTION

Our research over the last five years has shown that groundwater can contain form low levels (less than 1 μg/L) to high levels (over 1 gram/L) of a family of chemical compounds which can be classified as low solubility volatile [illegible] in Table I.

TABLE I. LOW SOLUBILITY VOLATILE COMPOUNDS FOUND IN MANY CONTAMINATED WATERS.

Aliphatics:	Propane up to C_{10} straight or branched chain hydrocarbons
Aromatics:	Benzene, toluene, ethylbenzene, etc.
Chlorinated aromatics:	Mono and Dichlorobenzenes, etc.
Chlorinated (Halogenated) Alkanes:	Chloroethane, methylene chloride, 1,1- and 1,1,1- and other chloroethanes, trihalomethanes, and higher molecula weight halogenated alkanes.
Chlorinated ethenes:	Vinyl chloride, vinylidene chloride, cis and trans 1,2-dichloroethylene, trichloroethylene and tetrachloroethylene.

Many of these compounds are included in the Environmental Protection Agency Priority Pollutant List. The list in Table I is by no means complete. This report covers our research work on 1.) anaerobic transformation of parent compounds introduced in the aquifer, 2.) transport of parent and biodegraded daughter compounds in the aquifer as measured at actual contaminated aquifer sites and 3.) decontamination of an aquifer site with resulting reclamation and use of the contaminated water.

Source of Contamination

We have studied actual contaminated aquifer sites to a depth of approximately 200 feet, finding the compounds listed in Table I. The source of many of the compounds listed in Table I is the result of the original compound accidentally spilled or dumped on the ground. For example, hydrocarbon fuels contain the aliphatic and aromatic hydrocarbons listed in Table I. Also, some of the chlorinated methane, ethane and ethylene compounds originate from usage of the common cleaning and degreasing compounds listed in Table II.

TABLE II. ANNUAL U.S. PRODUCTION (1979) OF FOUR CHLORINATED SOLVENTS

	lbs.
Methylene Chloride	625,000,000
1,1,1-Trichloroethane	700,000,000
Trichloroethylene	325,000,000
Tetrachloroethylene	750,000,000
Total	2,400,000,000

Our initial research work was prompted by the presence of compounds in the aquifer, supplying our drinking water plants, which seemed to have no logical source. These included such compounds as vinyl chloride, 1,1-dichloroethene, cis and trans 1,2-dichloroethene, 1,1-dichloroethane and chloroethane. These latter chemicals are either not actually produced or are not in wide use across the whole country as are the parent compounds in Table II. In Ref. 1, we showed that these compounds in the aquifer are the result of anaerobic biodegradation of the three latter parent compounds listed in Table II.

Anaerobic Transformation of Parent Compounds

In Ref. 1., we showed in the laboratory that anaerobic bacteria found in groundwater were able to transform parent compounds into the following daughter compounds:

Carbon tetrachloride ——> chloroform ——> methylene chloride

Tetrachloroethylene ——> trichloroethylene ——> [cis 1,2-dichloroethene / trans 1,2-dichloroethene / 1,1-dichloroethene] ——> vinyl chloride

1,1,1-trichloroethane ——> 1,1-dichloroethane ——> chloroethane

The laboratory work resulted in biodegradation half-life values for the parent and daughter compounds (based on our particular laboratory conditions) as shown in Table III. A half-life value of "long" represents no detectable reduction of the compound under the test conditions over a time period of observation averaging 30 to 60 days.

TABLE III. BIODEGRADATION AND PHYSICAL PROPERTIES OF INTEREST ON THE VOLATILE ORGANICS FOUND IN GROUNDWATER

	bio half-life (days)	solubility PPM	H_{IPC}	% removal per four series aeration stage
vinyl chloride	long	2700?	5.2	94
trans 1,2-dichloroethene	long	6300	0.16	87
cis 1,2-dichloroethene	long	3500	0.29	85
1,1-dichloroethene	53	8000	0.62	88
trichloroethylene	43	1100	0.48	86
tetrachloroethylene	34	130	1.2	89
methyl chloride	est.<11	—	—	—
methylene chloride	11	19400	0.1	82
chloroform	36	8200	0.15	87
carbon tetrachloride	14	800	0.97	89
bromodichloromethane	—	6060	0.099	82
chlorodibromomethane	—	5190	0.043	80
bromoform	—	4240	0.023	78
chloroethane	10	—	—	—
1,2-dichloroethane	long	8700	0.05	80
1,1-dichloroethane	long	5100	0.24	84
1,1,2-trichloroethane	24	—	—	—
1,1,1-trichloroethane	16	720	1.2	89
benzene	—	1780	0.23	85
chlorobenzene	—	488	0.13	85
p-dichlorobenzene	—	79	0.11	82
o-dichlorobenzene	—	145	0.083	81

In some of the laboratory work using different actual muck-water samples, we found bacteria profiles which seemed to result in loss by biodegradation of injected parent compound, tetrachloroethylene, with only trace amounts of daughter compounds detected. Thus, as the aquifer bacteria profile changes, different end results may occur. Anaerobic bacteria were isolated from groundwater and muck-water samples and cultured in laboratory media in the presence of tetrachloroethylene. Tentative conclusions on biodegradation of tetrachloroethylene by specific bacteria were as follows:

1. C. cadaveris and/or C. limosum and/or G+ cocci (tetrads) may, in the course of biodegrading tetrachloroethylene, favor the heavy growth of trichloroethylene and cis 1,2-dichloroethene, with some methylene chloride and/or 1,1-dichloroethene production.

2. Big G+ rods and filaments (2 x 10 Trichome) may, alone or in the presence of G+ cocci (tetrads), result in tetrachloroethylene biodecay with minor formation of chlorinated by-products.

3. C. limosum alone may result in tetrachloroethylene biodecay with minor formation of chlorinated by-products. The same applies to a mix of P. maltophilia and P. fluorescens and P. fluorescens alone.

4. P. maltophilia alone may favor heavy growth of chlorinated by-products.

5. G-short, wide rods alone may result in the fastest biodecay of tetrachloroethylene of all the single and combinations of bacteria tested (this honor is probably equally shared by P. fluorescens alone).

6. Proteus vulgaris alone seems to result in biodecay of tetrachloroethylene with minor growth of chlorinated by-products.

7. E. cloacae, E. coli, and P. aeruginosa alone allow growth of chlorinated by-products, including some vinyl chloride in our limited 17-day test.

8. Large G+ rods alone seem to favor minor growth of chlorinated organic by-products as it biodecays tetrachloroethylene.

Examination of actual aquifer contamination sites supported the findings in our laboratory work.

In a site where only trichloroethylene was spilled underground, in wells downstream were found the parent compound and the expected daughter compounds cis and trans 1,2-dichloroethene, 1,1-dichloroethene and vinyl chloride. In the laboratory we had previously found that biodegradation of either tri or tetrachloroethylene resulted in production of cis over trans 1,2-dichloroethylene isomer by a factor of perhaps 25 to 1 or more. This was confirmed in the above spill site. This was confirmed in other actual spill sites where tri and/or tetrachloroethylene was present. In other sites, we also confirmed that 1,1,1-trichloroethane biodegrades to 1,1-dichloroethane, chloroethane and methylene chloride.

Transport of Parent and Daughter Compounds in the Aquifer.

In actual contaminated aquifer sites, we were involved in detailed mapping of the original spill area and establishing the boundries of the downstream contamination plume. This work extended to an approximate maximum depth of 200 feet and a downstream distance of two miles. It was estimated that some of the initial spills were perhaps fifteen or more years old. In this work, it soon became apparent that as investigations were made of the plume further form the initial spill site, patterns were developing in the types and ratios of specific compounds found. Analysis of these patterns suggested that there might be some predictability in what might be found based on what was actually found in the sites investigated. Our observations suggested that the biodegradation half-life values reported in Table III might assist in explaining and thus predicting what compounds have been and might be found at progressingly further distances from the initial spill site. Also, knowing what compound was initially spilled, the half-life values along with our findings on the favored ratio of cis over trans 1,2-dichloroethene might allow predicition of what daughter compounds would form and perhaps their ratios. Also, perhaps based on what compounds are found, one might project to the initial parent compound spilled, eventhough it perhaps no longer existed at the site studied.

The biodegradation half-life values reported in Table III represent our findings in the laboratory under our particular test conditions. We do not suggest that they define an actual spill condition. From actual sites where spills occured perhaps more than 15 years ago, we have

5. G-short, wide rods alone may result in the fastest biodecay of tetrachloroethylene of all the single and combinations of bacteria tested (this honor is probably equally shared by P. fluorescens alone).

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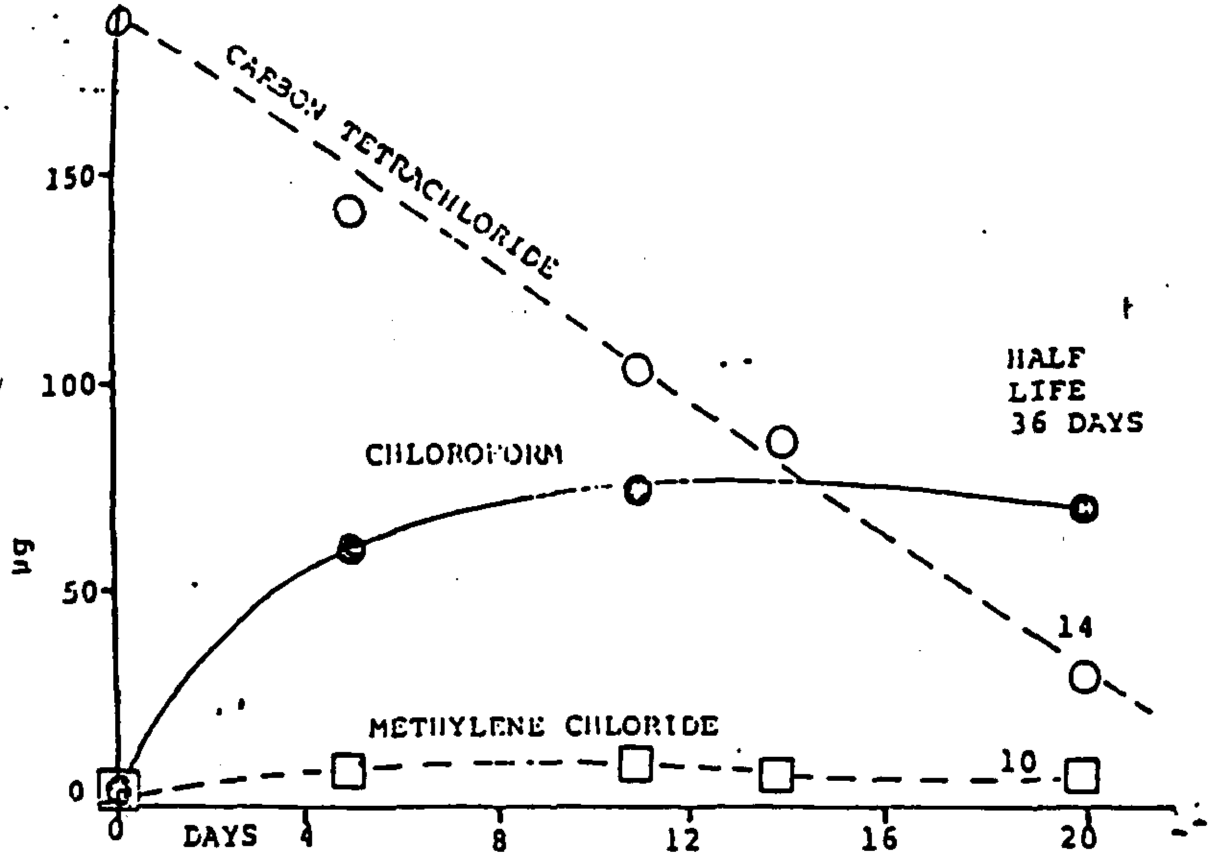


Figure 1. Decay of Carbon Tetrachloride and Increase of Daughter Compounds

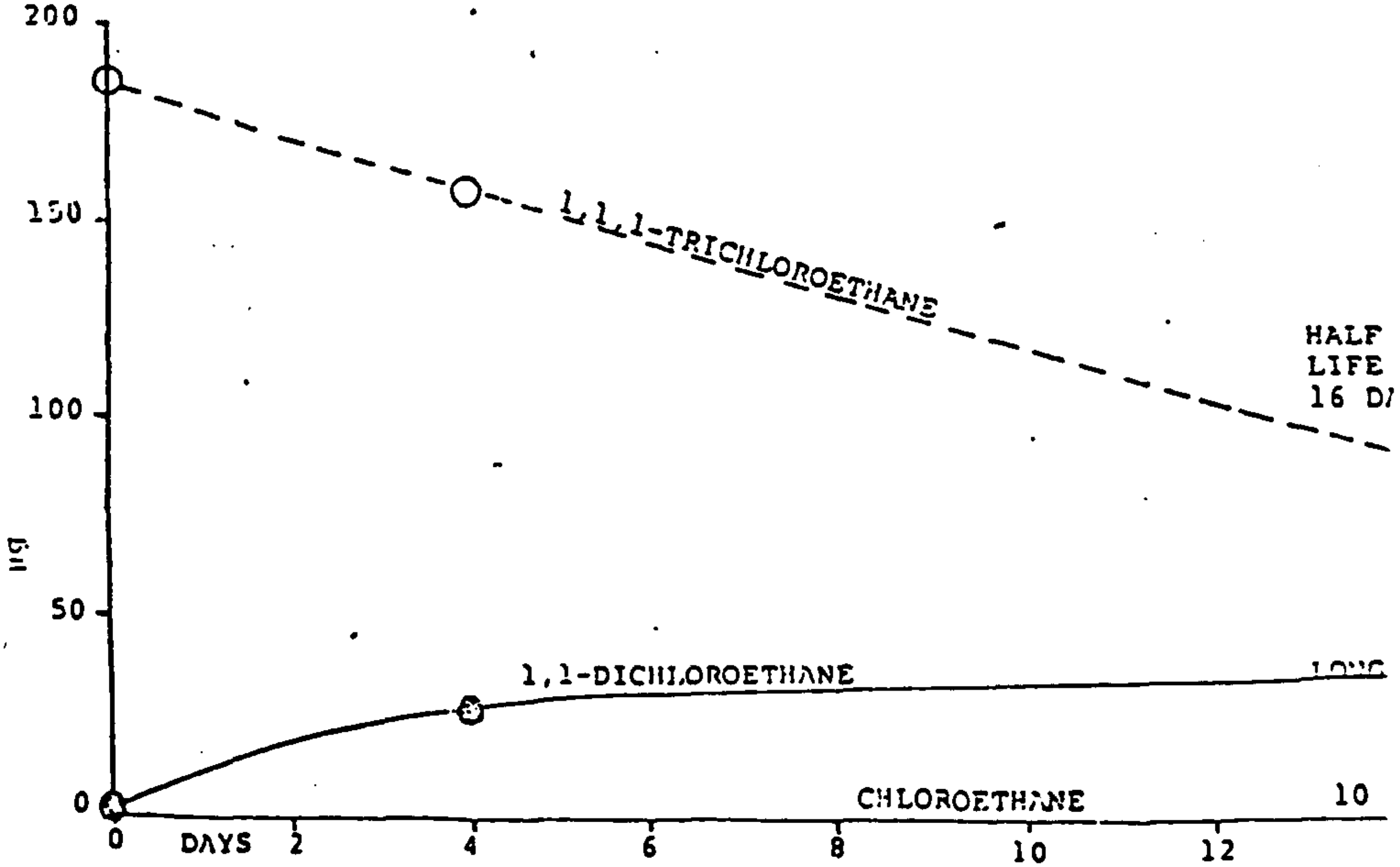


Figure 2. Decay of 1,1,1-trichloroethane and Increase of Daughter Compounds

trichloroethane in Figure 2, and for tetrachloroethylene in Figure 3.

Decontamination of Aquifer and Water Reclamination.

It was recognized that at a spill site, it would be desirable to have a practical method of decontaminating the initial spill site and the downstream aquifer to prevent the spread of the contamination plume and reclaim the contaminated water. These were the topics of our research reported in Ref. 2, a great deal of which was based on our aeration research work in Ref. 3.

An actual spill site was chosen, but before a spray head aeration system could be designed for the specific site, it was necessary to determine the parameters affecting rate loss of the volatile compounds by spray head aeration. Spraying Systems Co., Wheaton, Ill., supplied a series of spray nozzles. The series covered a wide range of water flow rates and spray pattern types as available in their Industrial Catalog 27. Some of the nozzle types studied are listed in Table IV.

TABLE IV. SOME OF THE SPRAY SYSTEMS CO. SPRAY NOZZLES STUDIED IN THIS PROJECT

Nozzle No.	Spray Pattern	Water flow rate gal/min
4 CRC 250	Hollow Cone (45°)	300 at 10 psi
1 1/2 H 20	Full Cone (74°)	24 at 10 psi
2 H 35	Full Cone (75°)	42 at 10 psi
2 H 47 W	Full Cone (124°)	55 at 10 psi
2 H 151150	Full Cone (15°)	58 at 10 psi
2 H 50	Full Cone (83°)	59 at 10 psi
4 H 154500	Full Cone (15°)	225 at 10 psi
4 RR 65160	Full Cone (65°)	279 at 10 psi
3/4 FF-18	Fog jet	13 at 20 psi
1 1/2 29F-35	Fog jet	25 at 20 psi
1 1/4 FF-70	Fog jet	50 at 20 psi

The above nozzles were tested individually at well sites with varying levels of volatile organic chemical concentrations, ranging from combined levels of contamination of over one hundred thousand μg/L to very low levels of less than 10 μg/L. The nozzles were positioned eight feet above the ground and sprayed either up or down at varying water flow rates and pressures. When the spray pattern was directed upward, the average distance of water droplet travel was estimated. Some of the data obtained are presented in the following log H_{ipc} versus percent removal graphs.

In Figure 4., a plot of log H_{ipc} versus percent removal for six contaminants at total contaminant levels of 11 μg/L, 131 μg/L, 4648 μg/L and 130,170 μg/L shows that for a spray head aeration system, as found or other aeration systems in Ref. 2, the rate loss is the same regardless of concentration (as long as contaminants are completely dissolved).

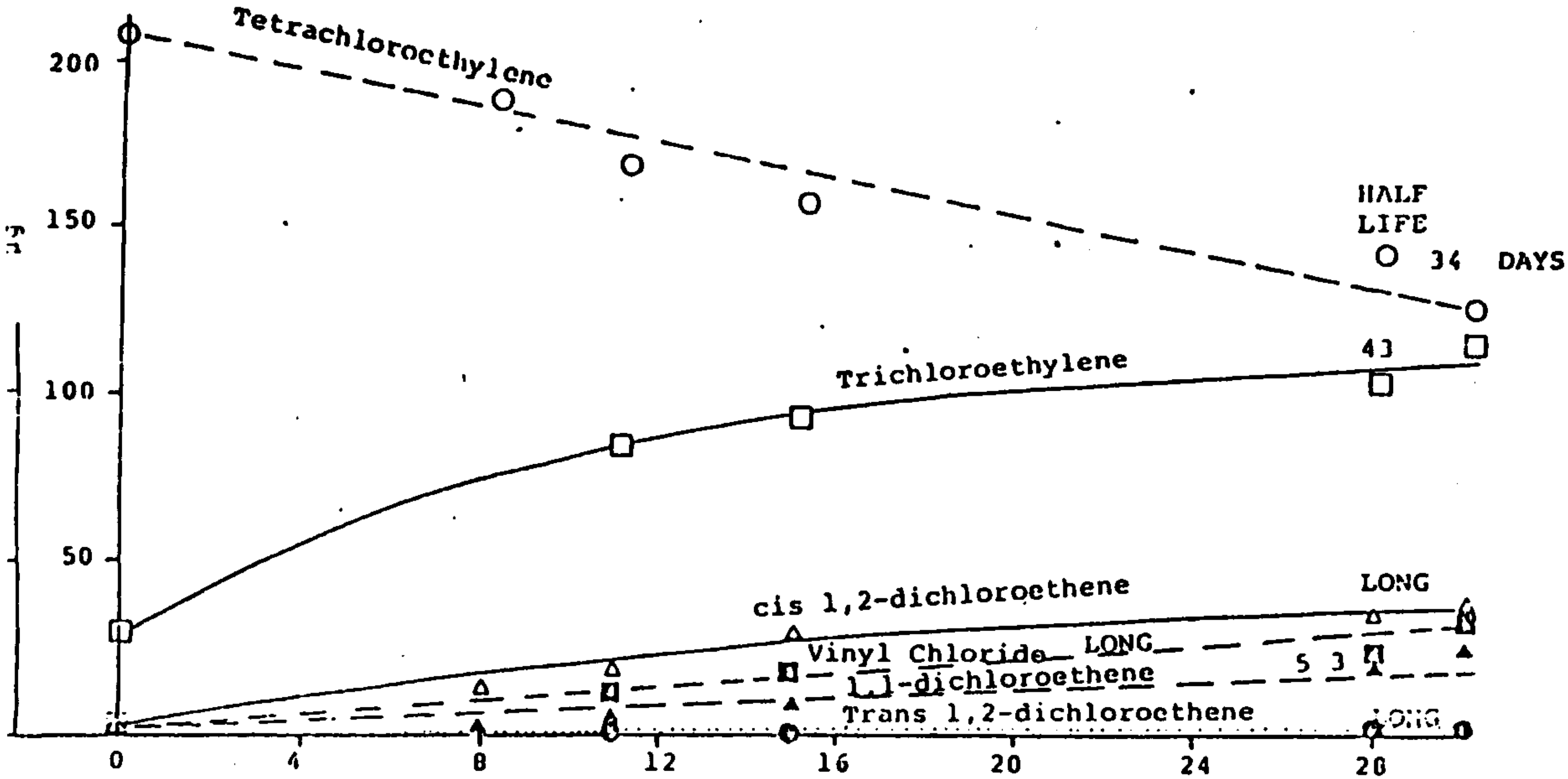


Figure 3. Decay of Tetrachloroethylene and Increase of Daughter Compounds

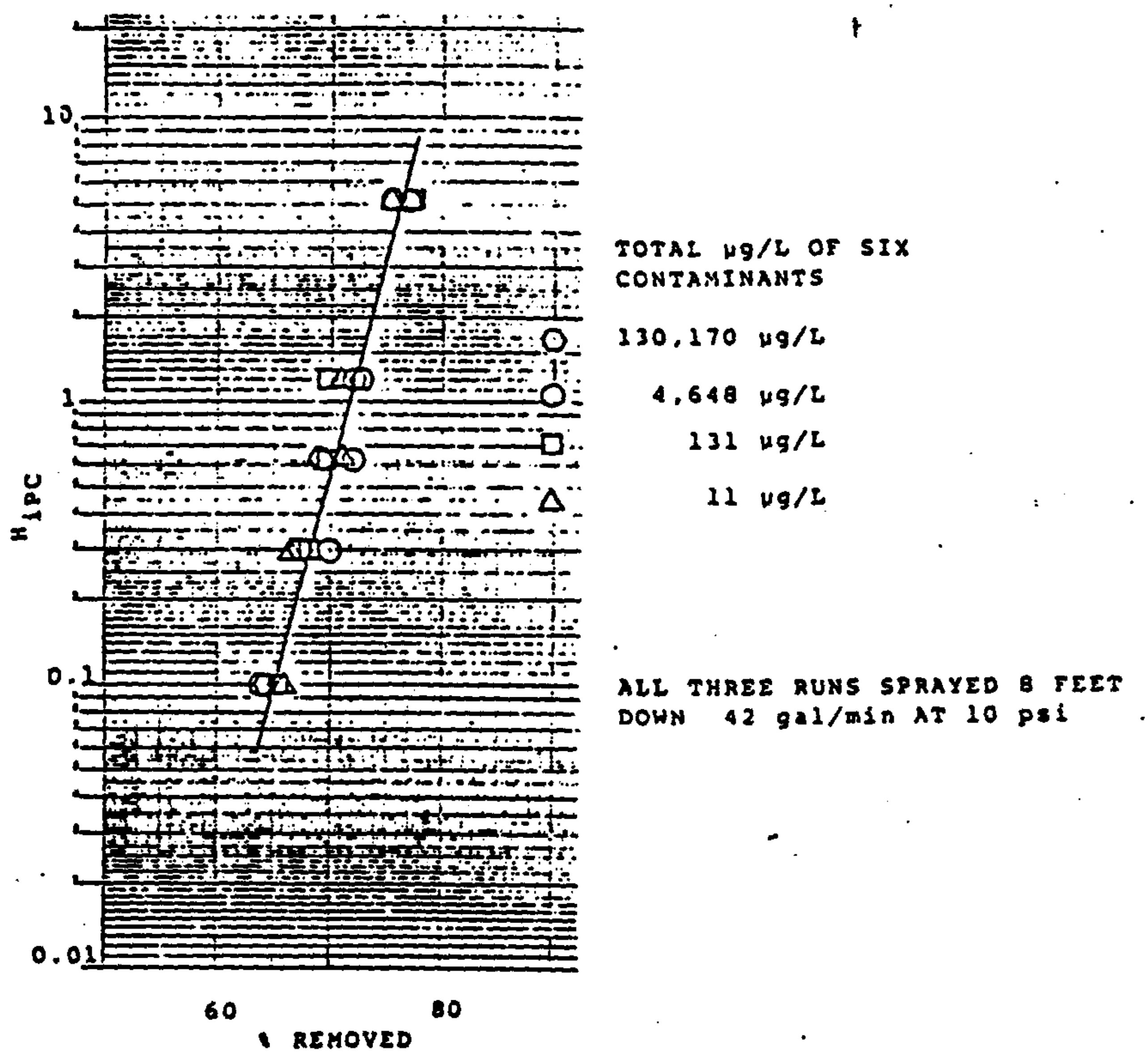


FIGURE 4. REMOVAL DATA FOR SIX CONTAMINANTS THROUGH SPRAY NOZZLE 2H35

tems, that in a spray head aeration system, log H_{ipc} versus percent removal is approximately a straight line plot. For any aeration system, once this plot is established, with at least data points for two compounds, then the rate loss in the system for any volatile compound can be predicted if its H_{ipc} is known. Also, from such a plot if the initial concentration for any compound in water is known, we can predict the final concentration after one or more passes through the spray head system and thus can design a system to achieve any final concentration desired, including zero.

Figures 5, 6, and 7, show the removal results through three spray heads, sprayed down eight feet and then up starting at the same level of eight feet. The water flow rate and psi (energy input) was the same when sprayed up or down. In each case the average distance of water droplet travel was estimated. For the same energy input, spraying upward resulted in a much greater percent removal in all three cases. The average water droplet travel distance for the upward spray was 24 feet, 16 feet and 32 feet in Figures 5, 6 and 7 respectively, compared to 8 feet in the downward spray. From all the data collected, it became apparent that the droplet travel distance was the controlling factor in the removal rate. For example, this is illustrated by the vinyl chloride data in Figure 5. In the downward spray test, the initial concentration of vinyl chloride was 232 µg/L and spraying eight feet down reduced the concentration to 53 µg/L, a removal rate of 77 percent. In the upward spray test run, where the average droplet travel distance was 24 feet, the initial concentration was 220 µg/L and the final concentration was 2.3 µg/L, a removal rate of 99 percent. We can consider the data in two ways; one, if the eight feet down test was performed three times in series with a removal rate of 77 per pass, the initial concentration of 232 µg/L would be reduced to 2.8 µg/L, which is very close to the 2.3 µg/L obtained in the upward spray test which was equal to a series of three eight-feet droplet travel times (24 feet÷8 feet = 3), of two, we can take the upward spray data and calculate the percent removal for three eight feet passes in series. This calculates out to 78 percent removal per eight feet section.

initial conc = 220	µg/L x (.22) =	48	µg/L
48	µg/L x (.22) =	10.6	µg/L
10.6	µg/L x (.22) =	2.3	µg/L

This eight feet section removal value for each compound in the upward spray test is plotted in Figure 5, and they all fall near the linear curve in Figure 5 for the eight feet downward spray test. The same calculations are shown in Figures 6 and 7. Thus, it appears that the rate loss is proportional to droplet travel distance. If the rate loss is determined for any unit distance, eight feet for example, we can calculate the rate loss for any other travel distance.

Early in the spray head research program, it became obvious that a hollow cone spray pattern was undesirable.

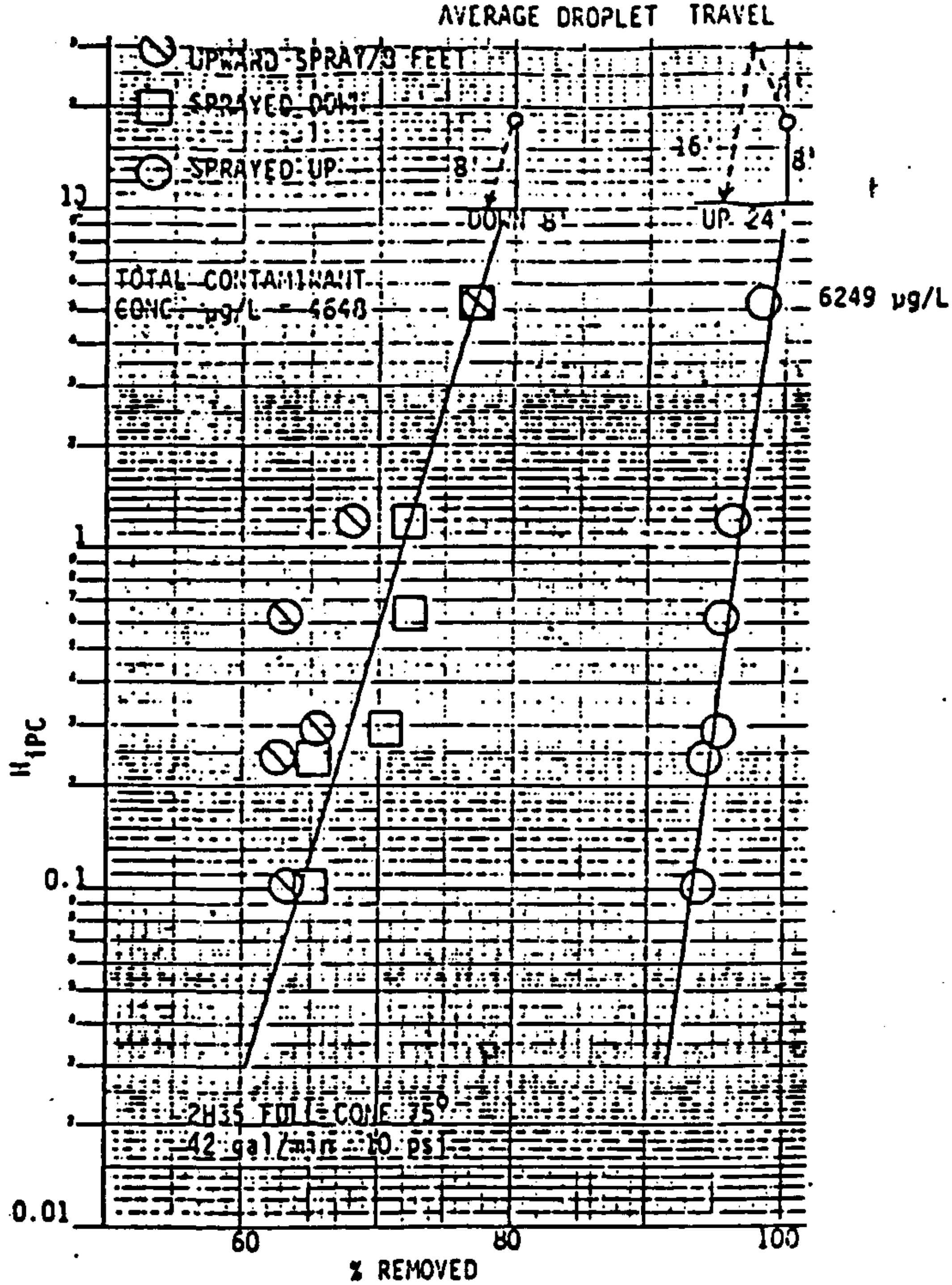


FIGURE 5. PERCENT REDUCTION OF SIX CONTAMINANTS THROUGH SPRAY HEAD 2H35 SPRAYED UP AND DOWN

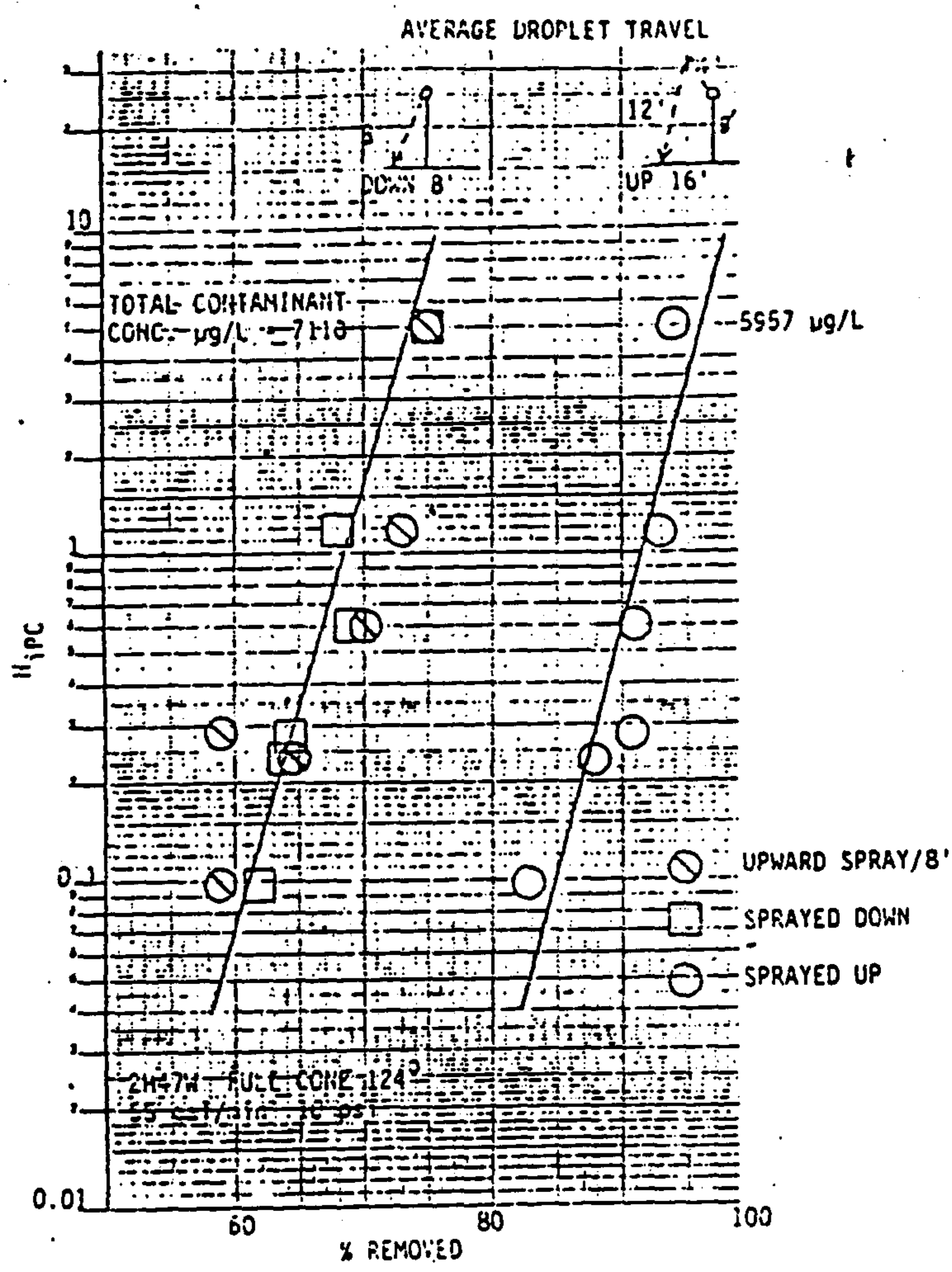


FIGURE 6. PERCENT REDUCTION OF SIX CONTAMINANTS THROUGH SPRAY HEAD 2H47W SPRAYED UP AND DOWN

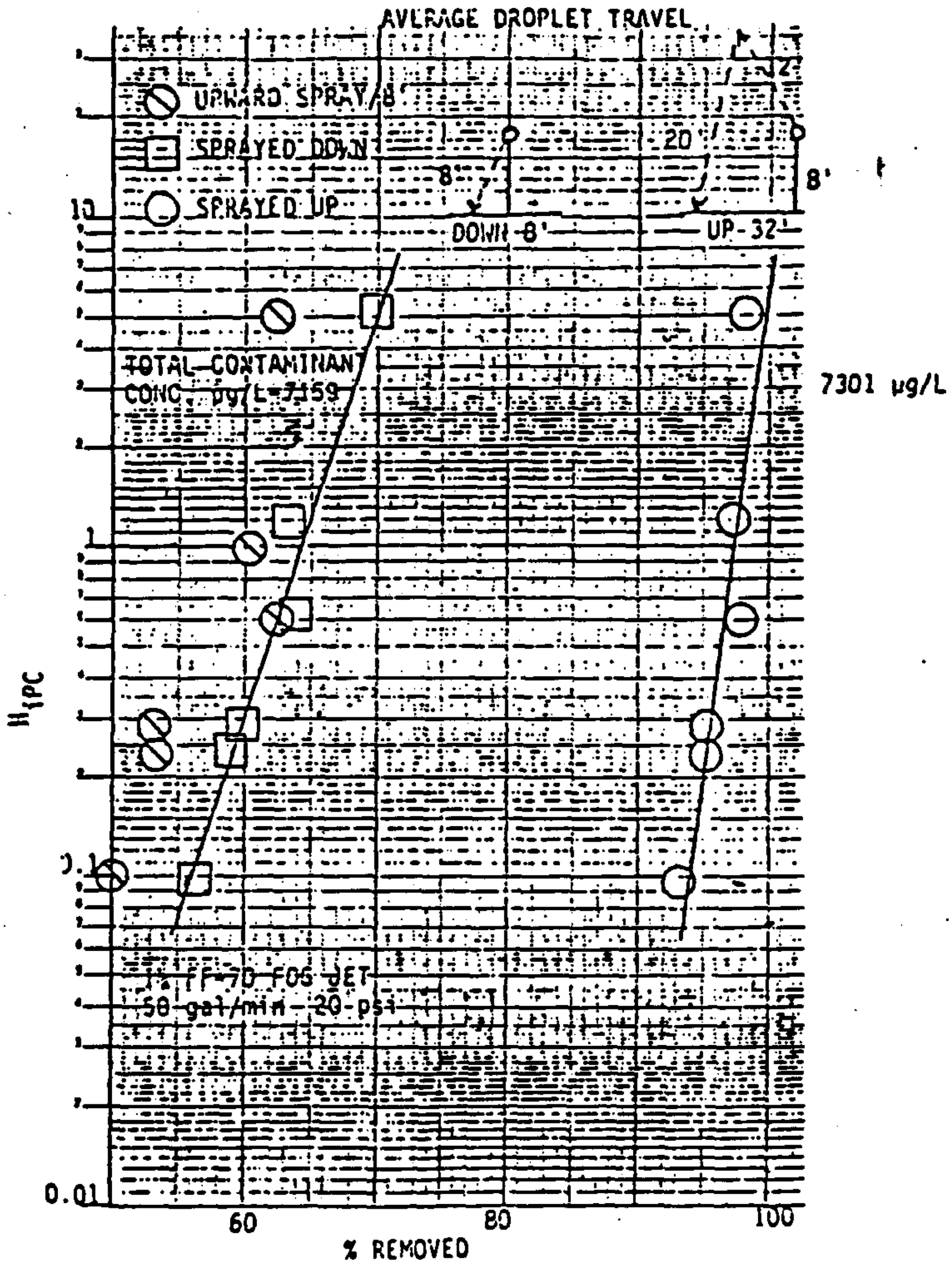


FIGURE 7. PERCENT REDUCTION OF SIX CONTAMINANTS THROUGH SPRAY HEAD 1¼ FF-70 SPRAYED UP AND DOWN

In a full cone spray pattern, the same volume of water would be broken up into smaller water droplets, resulting in higher percent removals. For comparison, even when nozzle 4CRC250 was sprayed upward, the removal rate was almost identical to the removal rate for nozzle 2H35 sprayed downward (Figure 5). Of course, the two tests cannot be directly compared since the water flow rates at 10 psi are different. Water droplet size greatly influences rate loss. The droplet size in the 4CRC250 run was much larger than in the 2H35 run. The effect of droplet size can be seen in Figure 8, where a series of full cone spray nozzles was studied. In all three runs at 10 psi, the average droplet travel distance was approximately equal. The major difference was in droplet size, larger as water volume increased. In Figure 8, the 24 and 42 gal/min heads gave much higher percent removals. Data points based on this one series of data do not show much difference between the 24 and 42 flow rates. Repeated runs would probably indicate a preference for the lower flow rate.

Spraying Systems fog nozzles produce the smallest water droplets. Results with three fog nozzles are shown in Figure 9. The fog nozzles require a minimum pressure of 20 psi for fogging to occur. However, the removal curve in Figure 9 for the 25 and 50 gal/min runs is almost identical to the curve in Figure 8 for the 24 and 42 gal/min runs using full cone spray nozzles. In Figure 9, the three data points for the 13 gal/min run appear to fall on a line to the right of the other two runs. In this run, 99 plus percent was being removed, making accuracy of data plots questionable. From all of the data, it appears that in general we desire a small droplet, but must weigh droplet size with other requirements. In our case where the water was to be purified and then used, maximum recovery of water was essential. Fog nozzles would result in losses due to partical drift. Therefore, for maximum recovery it was more efficient to use full cone nozzles.

Additional tests showed that nozzle 2H50 gave consistantly better removal rates than 2H35. Therefore, 2H50 was chosen for the spray head aeration system.

Spray Head Aeration System Design

The finished four stage series unit is shown in Figure 10. The first stage to be built was the elevated stage to the right. It was originally a cascade aerator with a single column approximately six feet tall in the center of a 17 by 17 foot basin reservoir. The basin reservoir capacity was increased and a 14 foot cypress wall box constructed over the basin to retain all the water spray. A nine inch air gap was maintained between the top of the concrete basin and the bottom of the cypress wall. Twenty 2H50 spray heads were equally spaced just above the water level in the basin, spraying upward at 10 psi, each head could handle a flow of approximately 60 gal of water per minute. The requirement was 1000 gal/min through the unit. Twenty spray heads would handle 1200 gal/min.

The top of the spray pattern was approximately two feet from the top of the cypress wall. The maximum droplet travel distance was approximately 26 feet, 13 feet up and

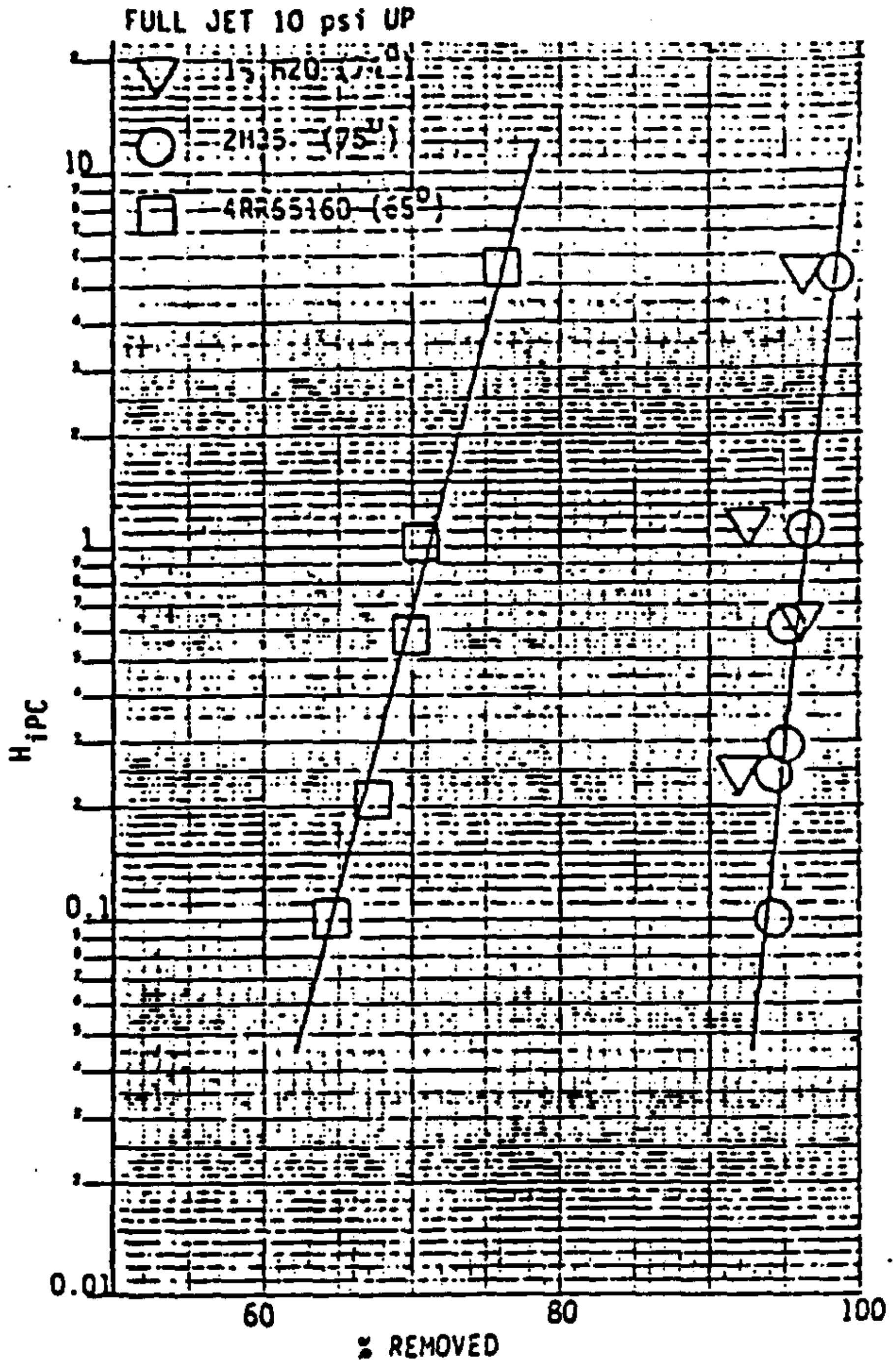


FIGURE 8. EFFECT OF WATER FLOW RATE ON PERCENT REMOVAL

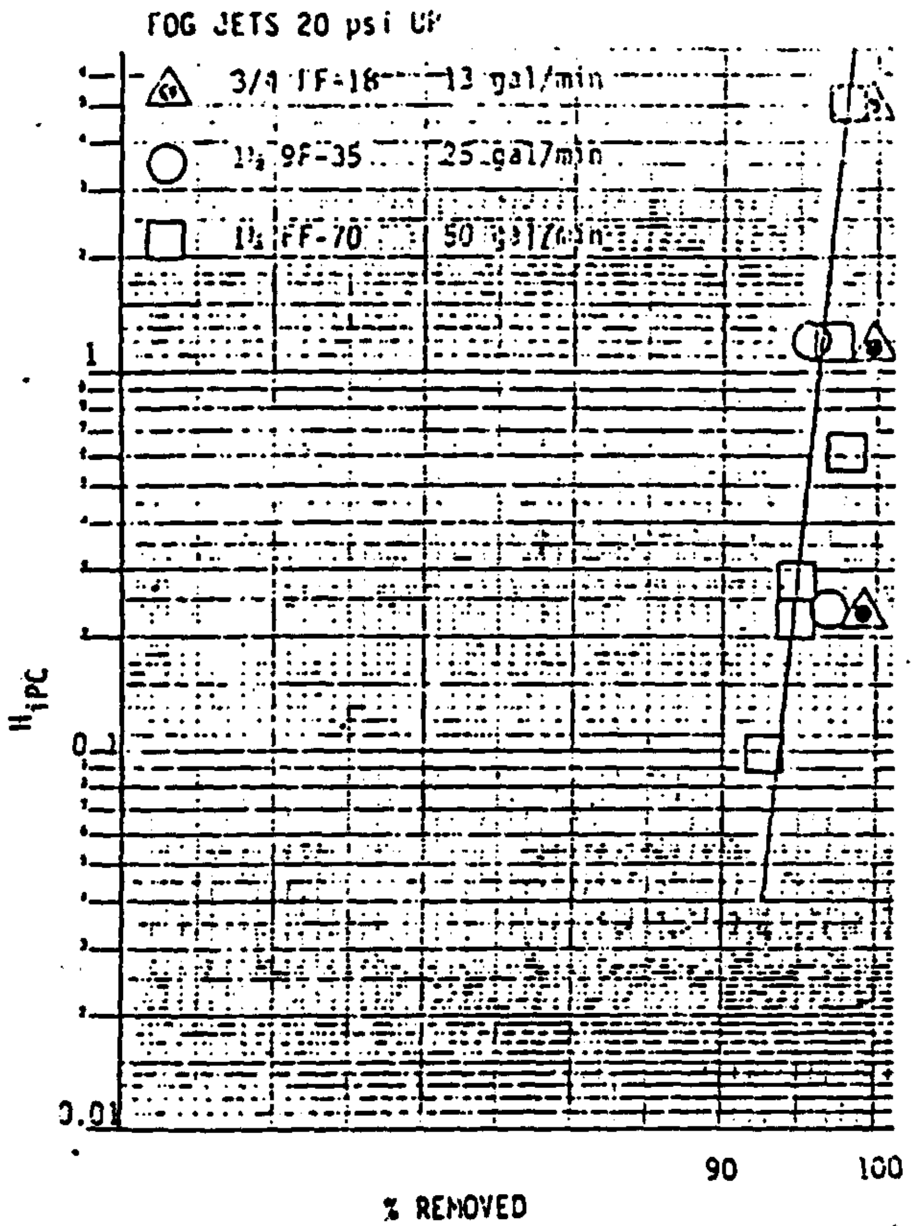


FIGURE 9. REMOVAL DATA USING FINE PARTICLE SPRAY FOG NOZZLES

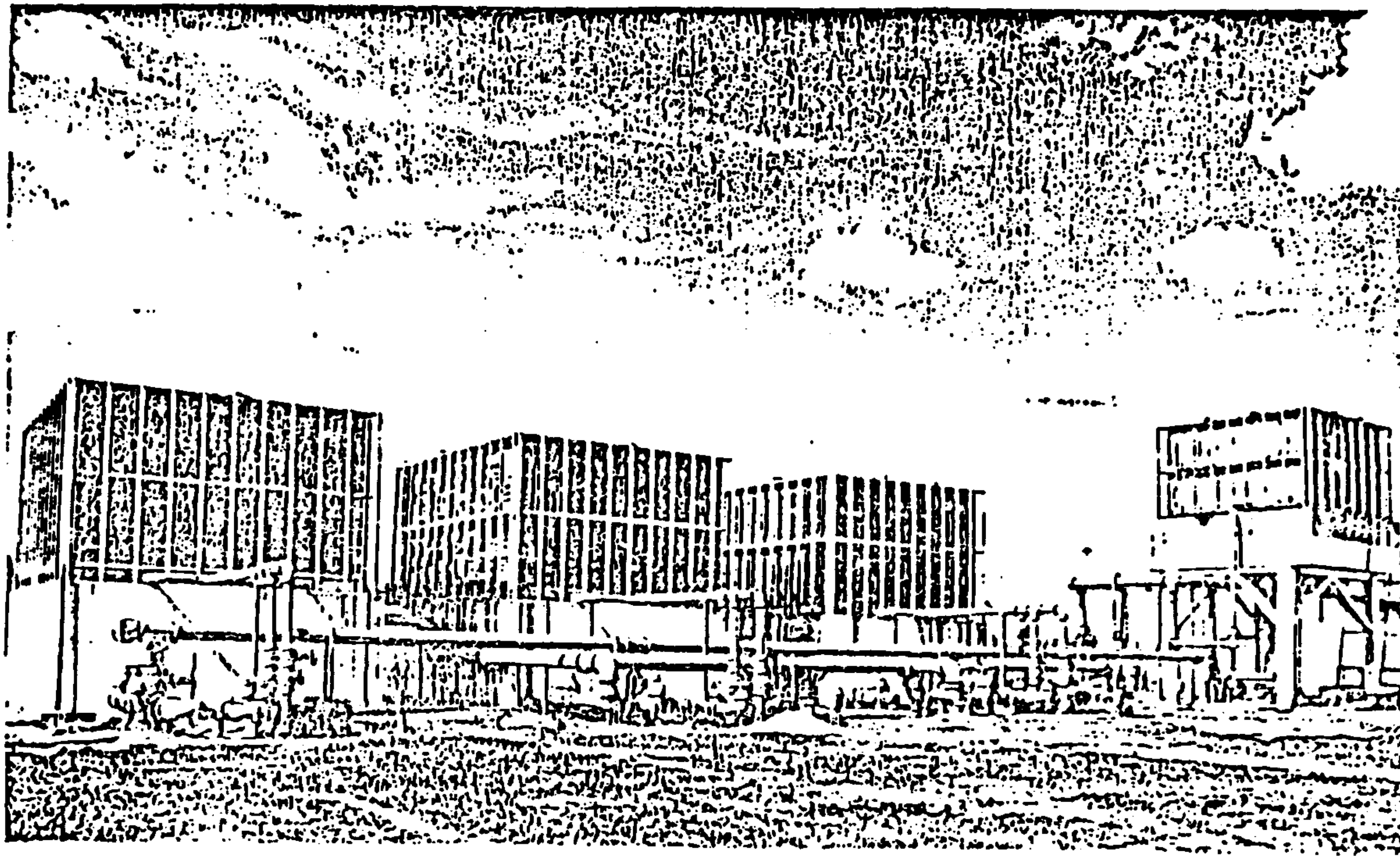


FIGURE 10. FOUR SERIES SPRAY HEAD AERATION SYSTEM INSTALLATION FOR AQUIFER DECONTAMINATION

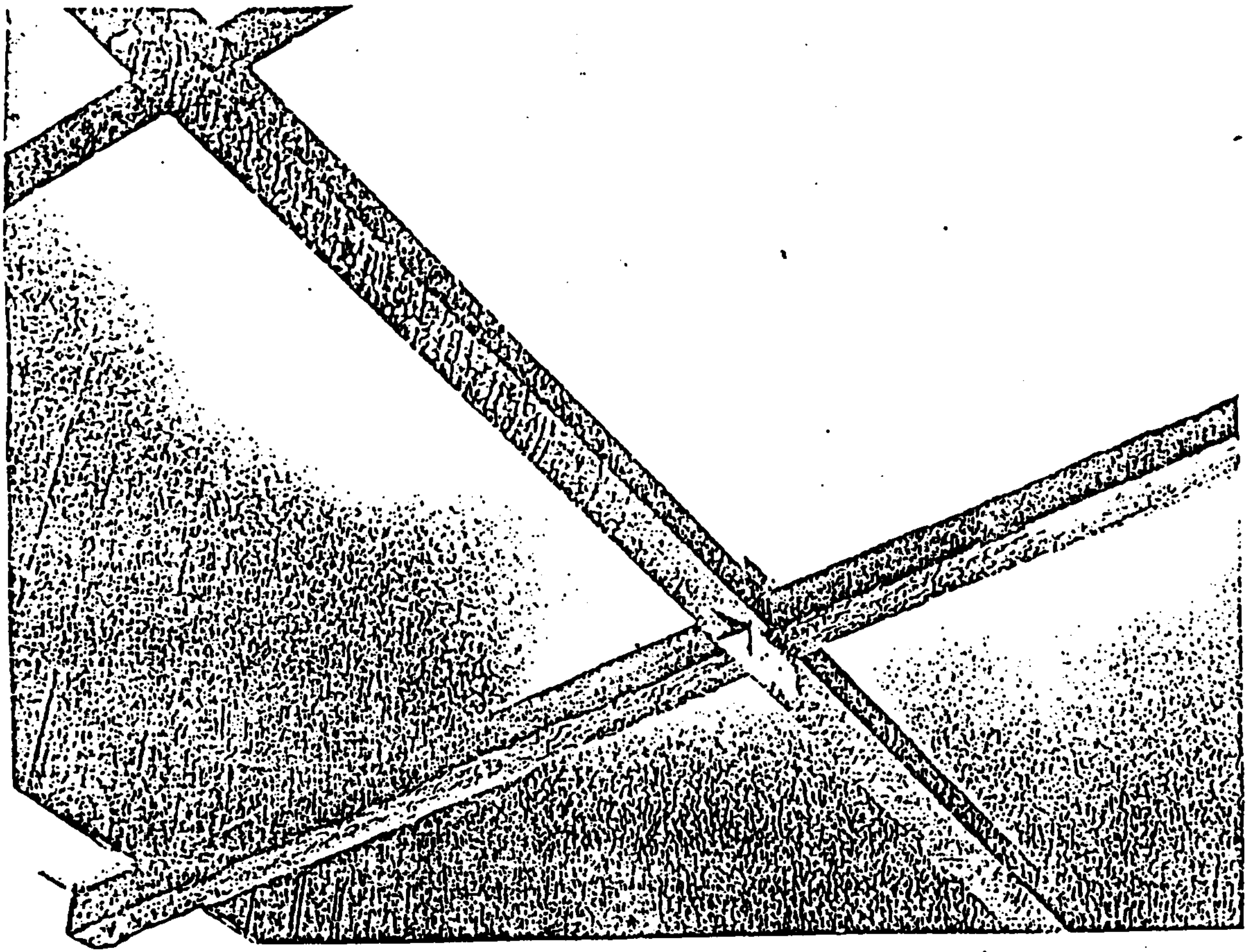
13 feet down. We had no idea how the individual nozzle spray patterns would interact with closely spaced neighboring nozzles. However, the performance of the unit was excellent, prompting design and construction of three more units in series. These units have a concrete reservoir base 20'x25'x6' deep (approximately 20,000 gal capacity). The cypress walls are 14 feet high, with a one foot air gap between the bottom of the cypress wall and top of the concrete wall. Again, twenty 2H50 spray heads were evenly spaced in each unit just above the surface of the water in the basin. The pump for each unit handled 1500 gal/min and the unit received 1000 gal/min from the wells. Thus, the pump draws 500 gal/min from the reservoir. A view down into the cypress walls is shown in Figure 11. After construction of the four stage aeration unit, it was tested with water from one well with high levels of contaminants. Results are shown in Table V.

TABLE V CONCENTRATION OF FOUR MAIN VOLATILE ORGANIC COMPOUNDS IN WATER ON INITIAL TEST RUN OF FOUR STAGE AERATION UNIT

	μg/L	
	entering 1st stage	4th stage effluent
Vinyl Chloride	665	0
1,1,1-Trichloroethane	1220	0.2
cis 1,2-dichloroethene	360	0.1
1,1-dichloroethene	3150	2.0

A plot of removal data for the first three stages is shown in Figure 12. Fourth stage data are not included because accuracy of data in the 0 to 0.1 μg/L range is doubtful. In Figure 12, it is apparent that the percent removal is approximately equal for all three stages, as expected. For example, considering removal data for 1,1,1-trichloroethane, approximately 89 percent was removed by each stage. The first stage received 1220 μg/L and reduced the value by 89 percent, to 134 μg/L. The second stage reduced this value to 15 μg/L. The third stage reduced this value to 1.6 μg/L. The fourth stages reduced this value to 0.2 μg/L.

The water droplet size from the 2H50 nozzles was large enough to result in minimal loss of water through the system by spray drift.



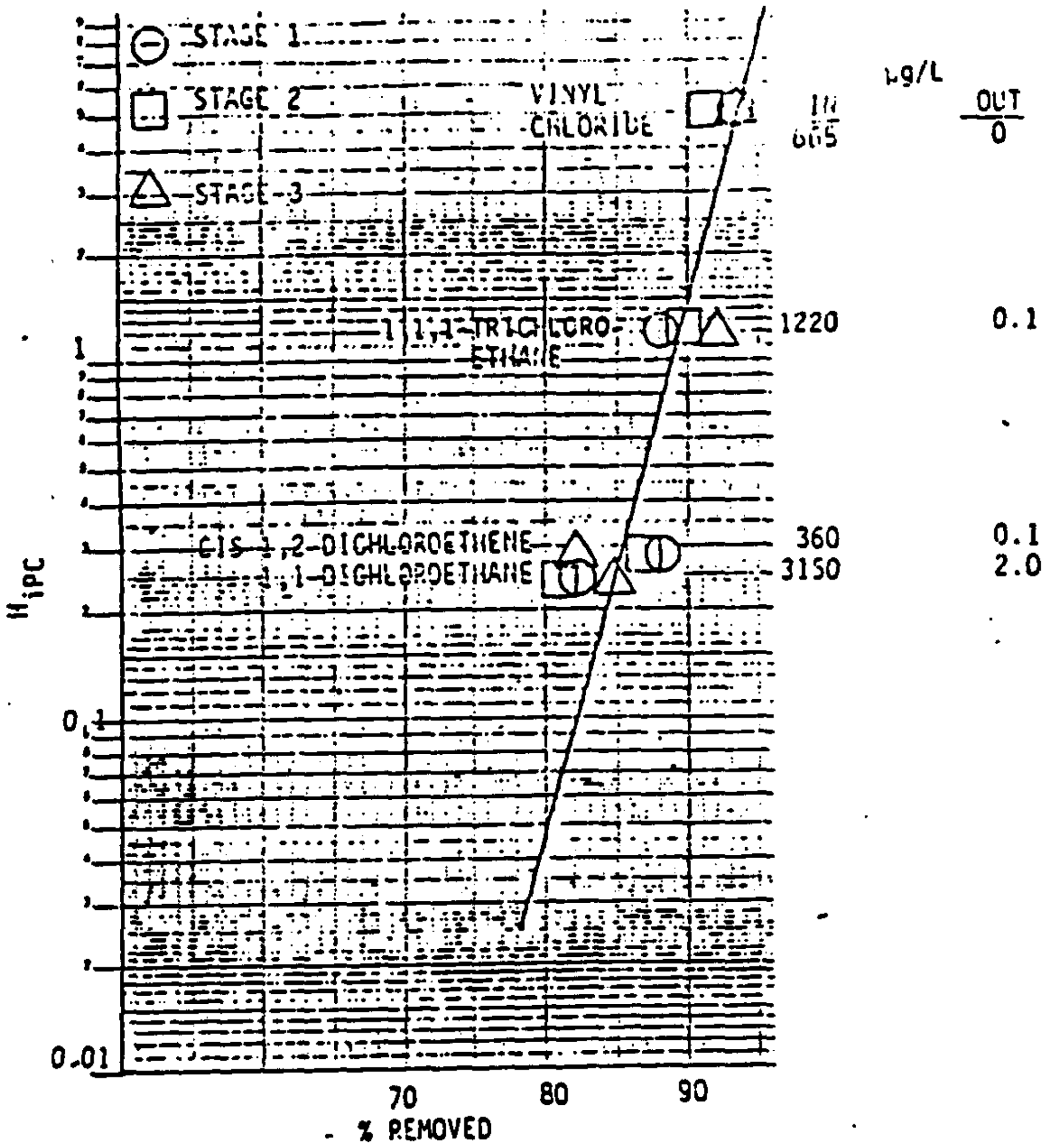


FIGURE 12. REMOVAL DATA FOR FIRST THREE STAGES IN FOUR STAGE SPRAY HEAD AERATION SYSTEM

The data in Table VI illustrates what the four stage unit would do if higher influent levels were introduced.

Table VI PROJECTED FOUR STAGE SPRAY HEAD AERATION UNIT PERFORMANCE ON HIGH CONCENTRATION VOLATILE ORGANIC CONTAMINATED WATER

	µg/L				
	Inlet conc.	1st stage effluent	2nd stage effluent	3rd stage effluent	4th stage effluent
vinyl chloride	10.000	600	36	2.2	0.1
1,1,1-trichloroethane	100,000	10,000	1,000	100	10
cis 1,2-dichloroethene	20,000	2,900	440	65	10
1,1-dichloroethane	15,000	2,440	390	63	10

Table III shows the percent removed per stage for a wide range of volatile organic contaminants based on H_{iPC}.

If recovery of the maximum amount of water through a spray head aeration system was not important, much greater removal rates could be achieved than shown in Tables III,V and VI. For example, using a 3/4 FF-18 fog jet nozzle (Table IV), the rate loss for 1,1-dichloroethane (the hardest compound in Table VI to remove) would be 15,000 µg/L to 150 µg/L to 1.5 µg/L in just three passes. Even higher removal rates would be achieved if the fog nozzle was positioned high off the ground.

After six months of operation, not only is the spray aeration system producing water of potable quality, but it is decontaminating the groundwater. By continuing to pump water from the wells in the contamination plume, down gradient movement of contaminants is prevented. Consequently, the well field-aeration system is acting as an effective contaminant containment and clean up scheme.

CONCLUSIONS

1. This study indicates that the source of the highly volatile chlorethene compounds, vinyl chloride, 1,1-dichloroethene, cis and trans 1,2-dichloroethene in our raw ground water is likely a result of biodegradation of trichloroethylene and/or tetrachloroethylene which are found widely spred in the environment as a result of our wide-spred use of these compounds.
2. A simple laboratory method was developed for assaying biodegradation of highly volatile chlorinated organic compounds in water, soils and sediments, and bacteria culture media.
3. All of the chlorinated methane, ethane and ethene compounds studied appear to be susceptible to biodegradation in the environment.
4. A rate of biodegradation technique, based on the assumption that the degradation slope observed was constant in the test conditions, appeared to provide a plausible answer or assigned biodegradation half life values for all the compounds tested under anaerobic conditions favoring daughter compound formation.
5. The bacterial population profile of a given system, which varies seasonally, appears to determine the intermediate biodegraded chlorinated organic compound profile in the system.

   Certain bacterial profiled, for example, will reduce all the tetrachloroethylene present in a given time, with the formation of only intermittent trace quantities of lower chlorinated compounds.

   Other bacterial profiles will reduce tetrachloroethylene with the formation of all possible lower chlorinated compounds present.
6. The resulting concentration of the lower chlorinated compounds may be dependent on the individual half life of each product and the favored end product of biodegradation in a given system.

   For example, biodegradation of tri- and/or tetrachloroethylene favors the production of cis over trans 1,2-dichloroethene by a factor of approximately 25:1. Therefore, while the biodegradation half life of the two compounds (cis and trans), in a bacterial profile system where they are formed, is long and perhaps equal, the concentration of cis will always be much greater than for trans.
7. Using an estimation of biodegradation half life technique for the families of chlorinated compounds studied, we may be able to understand and predict the chlorinated organic profile and transport in an environmental system after introduction of any single member of the family.

8. Field data from actual below-ground accidental spills of these halogenated parent compound in Florida and other states has confirmed our laboratory biodegradation results.
9. Tentative conclusions are presented for specific bacteria activity in the biodegradation of tetrachloroethylene under laboratory conditions.
10. Spray head aeration is very effective for removal of a wide range of volatile organic contaminants in water. No forced air is necessary. Spray heads are available covering a wide range of applications.
11. Predicting performance and designing systems is now possible based on our research, design and application.
12. Merits of such a system are; water reclamation and reuse, prevention of contaminated plume spreading in the aquifer and aquifer decontamination.

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APPENDIX H

"Lining of Waste Impoundment and Disposal Facilities"; Haxo, et al., "Liner Materials Exposed to Municipal Solid Waste Leachate" (1981)

United States
Environmental Protection
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Lining of Waste Impoundment and Disposal Facilities

LINING OF WASTE IMPOUNDMENT AND DISPOSAL FACILITIES

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CHAPTER 3

LINING MATERIALS AND LINING TECHNOLOGY

3.1 INTRODUCTION

The purpose of lining a waste disposal site is to prevent potentially polluting constituents of the impounded waste from seeping from the site and entering the groundwater or surface water system in the proximity of the site. The pollutants, as discussed in Chapter 2, include organic and inorganic materials, solids, liquids, gases, and bacteriological species. In their performance liners function by two mechanisms:

a. They impede the flow of leachates and thereby limit the movement of pollutants into the subsoil and thence into the groundwater. This requires a liner material having low permeability.

b. They absorb or attenuate suspended or dissolved pollutants, whether organic or inorganic, and reduce their concentrations so that they fall within the ranges set by the EPA for groundwater. This absorptive or attenuative capability is dependent largely upon the chemical composition of the liner material and its mass.

Most liner materials function by both mechanisms but to different degrees depending on the type of liner material and the waste liquid and its constituents. Membrane liners are the least permeable of the liner materials, but have little capacity to absorb materials from the waste. They can absorb organic material but, due to their small mass, their total absorption is small. Soils can have a large capacity to absorb materials of different types, but they are considerably more permeable than polymeric membranes. However, the greater the thickness of a given soil, the lower the flux through the liner. The choice of a particular liner material for a given site will depend upon many factors which are discussed throughout this Technical Resource Document. In this chapter, the major candidate materials for use as liners are discussed.

For the purpose of this Technical Resource Document, we consider a liner to be a material constructed or fabricated by man. Such a definition includes not only synthetic membranes and admixes but also soils and clays having low permeability which are (1) either brought to a site or available on the site and (2) remolded and compacted to reduce permeability.

Liners can be classified in a variety of ways, such as construction method, physical properties, permeability, composition, and type of service. These

d. The higher the moisture content during compaction, the more critically important is the density obtained, e.g. a small decrease in density (1%) may result in a permeability increase of one order of magnitude.

The subject of soil permeability will be discussed further in Chapter 4 and 5.

Chapter 4 will present more detailed information on the interaction between liquid chemistry, clay physicochemical and mineralogical properties, and permeability. The discussion will be made in the context of soil liner failure, i.e. an increase in permeability beyond the designed value.

Chapter 5 will present the information required to design a soil liner, the use of this information, and the permeability values to be reached in different circumstances.

3.3 ADMIXED LINING MATERIALS

3.3.1 Introduction

A variety of admixed or formed-in-place liners have been successfully used in the impoundment and conveyance of water. These linings include asphalt concrete, soil cement, and soil asphalt, all of which are hard-surface materials. The amount of experience in the use of some of the admixes in the lining of sanitary landfills and the lining of impoundments of brine is limited. Materials of this type have undergone exposure testing in contact with municipal solid waste leachate (Haxo and White, 1976; Haxo et al, 1982) in one EPA research project, and are undergoing limited exposure testing in a second project with hazardous wastes (Haxo et al, 1977). In this section the following types of admixes are discussed: hydraulic asphalt concrete, soil cement, and soil asphalt. Bentonite clay is also discussed in this section, as it is usually a processed product which is spread and mixed into on-site soil, and thus can be considered an admixed material.

3.3.2 Hydraulic Asphalt Concrete (HAC)

Hydraulic asphalt concretes, used as liners for hydraulic structures and waste disposal facilities, are controlled hot mixtures of asphalt cement and high quality mineral aggregate, compacted into a uniform dense mass. They are similar to highway paving asphalt concrete but have a higher percentage of mineral fillers and a higher percentage (usually 6.5 to 9.5) of asphalt cement. The asphalt used in hydraulic asphalt cement is usually a hard grade, such as 40-50 or 60-70 penetration grade. These harder asphalts are better suited as liners than softer paving asphalt (Asphalt Institute, 1976).

A major factor in the design of a hydraulic asphalt mix for use as a liner to confine wastes is the selection of an aggregate that is compatible with the waste. For example, aggregate containing carbonates must be avoided in HAC liners for acidic wastes.

Hydraulic asphalt concrete can be compacted to have a permeability coefficient less than 1 x 10^{-7} cm s^{-1}. It is resistant to the destructive wave action of water, light vehicular traffic, and effects of weather extremes (temperature). Such asphalt concrete is stable on side slopes, resisting slip and creep, and retains enough flexibility to conform to slight deformations of the subgrade and avoid rupture from low level seismic activity. Asphalt concrete liners may be placed with conventional paving equipment and compacted to the required thickness (Asphalt Institute, 1966).

Styron and Fry (1979) used 11 percent asphalt in a two-inch asphalt concrete liner to obtain the necessary permeability. Haxo et al (1982) used a nine percent asphalt concrete, but after one year of exposure to leachate from a simulated landfill, determined that due to potential inhomogeneities in the admixed materials, resulting from inadequate mixing or compaction, a liner thickness greater than four inches may be necessary to contain wastes (Table 3-3). The HAC liner examined after 56 months of exposure was in good condition; properties had changed very little since the first specimen was examined at one year of exposure. A study by Southern California Edison showed that an optimal compacted thickness, for a pond holding primarily water, was two layers of two inches each for a total thickness of four inches (Hinkle, 1976).

The quality of the finished liner depends on the compaction during placement (Bureau of Reclamation, 1963, p 40). The liner should be compacted to at least 97% of the density obtained by the Marshall Method (Asphalt Institute, 1976) or less than 4% voids (Asphalt Institute, 1981). Hinkle (1976) found that a voids content less than 2.5% produced a permeability of less than 0.001 ft/yr (1 x 10^{-9} cm s^{-1}), as shown in Table 3-4. Samples containing 8.5% asphalt at 97% compaction, in a pressurized permeameter, showed no observable flow (Hinkle, 1976).

Before placement of the liner, the subgrade should be properly prepared. It should not have side slopes greater than 2:1 and preferably no greater than 3:1 (Asphalt Institute, 1966). The soil should be treated with a soil sterilant to prevent puncture of the liner by weeds and roots (Asphalt Institute, 1966). Mixtures of sodium chlorate and borates are examples of such soil sterilants (Bureau of Reclamation, 1963).

Asphalt has been used for centuries as a water resistant material. More recent usage has shown that asphalt materials also are resistant to acids, bases, inorganic salts (to a 30% concentration) and to some organic compounds found in industrial wastes (Asphalt Institute, 1976). Asphalts are generally not resistant to organic solvents and chemicals, particularly hydrocarbons in which they are partially or wholly soluble. Consequently, asphalts are not effective liners for disposal sites containing petroleum derived wastes or petroleum solvating compounds such as oils, fats, aromatic solvents, or hydrogen halide vapors. Asphalt does show good resistance to inorganic chemicals and low permeability to corrosive gases such as hydrogen sulfide and sulfur dioxide.

are of low molecular weight, e.g. asphalt, and may interact adversely with many wastes. Some of the new materials that are being introduced are of high molecular weight or contain polymeric additives which improve their durability.

In this section, the following materials are discussed; airblown asphalt, emulsified asphalt, urethane modified asphalt, and rubber and plastics, in either liquid or latex form.

3.5.2 Air-blown Asphalt

Membranes of catalytically-blown asphalt are the most commonly used sprayed-on linings. The asphalts used in making these membrane linings have high softening points and are manufactured by blowing air through the molten asphalt at temperatures in excess of 500°F in the presence of a catalyst such as phosphorous pentoxide or ferric chloride. To prepare the membrane, the asphalt is sprayed on a prepared soil surface at a temperature of 400°F, at a pressure of 50 psi through a slot-type nozzle, and at a rate of 1.5 gal yd^{-2} (Bureau of Reclamation, 1963, p. 80). The finished liner is usually 0.25 inch thick (Bureau of Reclamation, 1963, p. 79), formed by two or more passes of the spray device and overlapping sections by one or two feet (Clark and Moyer, 1974). It can be placed during cold or wet weather, in large quantities, by mobile equipment (Bureau of Reclamation, 1963, p. 10). Sprayed-on membranes retain their tough flexible qualities indefinitely when properly covered and protected from mechanical damage (Asphalt Institute, 1976). The actual placing of the earth covers on a sprayed-on membrane may cause some damage to its integrity.

Studies have shown the addition of 3-5% rubber improves the properties of the asphalt by inducing greater resistance to flow, increased elasticity and toughness, decreased brittleness at low temperatures, and greater resistance to aging (Chan et al, 1978, p. 17).

Bituminous seals are used on asphalt concrete, portland cement concrete, soil asphalt, or soil cement linings to close pores, thus improving waterproofing or when there may be a reaction between the stored liquid and the lining. The two types of seals usually applied are:

a. An asphalt cement sprayed over the surface about one qt yd^{-2} to form a membrane about 0.04 in. thick.

b. An asphalt mastic containing 25 - 50% asphalt cement, the rest being a mineral filler, squeegeed on at 5 - 10 lb yd^{-2}.

Installation of sprayed-on asphaltic membranes is usually done on a subgrade which has been dragged and rolled to obtain a smooth surface. If there is an excessive number of irregular rocks and angular pieces, a fine sand or soil "padding" is necessary for good membrane support (Bureau of Reclamation, 1963, p. 81). Covering protects the membrane from most mechanical damage.

A special deep penetration formula of liquid cutback asphalt was applied over natural-on-site soil at a rate of two gal yd^{-2}. The seepage rate, in this

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE LINER MATERIALS EXPOSED TO MUNICIPAL SOLID WASTE LEACHATE		5. REPORT DATE 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) H. E. Haxo, Jr., R. M. White, Paul D. Haxo, and M. A. Fong		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Matrecon, Inc. P. O. Box 24075 Oakland, CA 94623		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-03-2134
12. SPONSORING AGENCY NAME AND ADDRESS Muncipal Environmental Research Laboratory--Cin, OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268		13. TYPE OF REPORT AND PERIOD COVERED Final, 1/1/76 - 1/31/81 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

See also "Evaluation of Liner Materials Exposed to Leachate", EPA 600/2-76-255, 1976, (NTIS PB-259913), and "Liner Materials Exposed to MSW Leachate", EPA-600/2-79-038, 1979.

16. ABSTRACT

The results of the exposure testing of 65 lining and related materials to MSW leachate for periods of up to 56 months are reported. The materials include 4 admix materials, 2 asphalt membranes, 50 commercial flexible polymeric membranes, and 9 miscellaneous materials, but exclude soils and clays. The principal thrust of the project was to expose 12 primary liners for 12 and 56 months as barrier specimens in 24 landfill simulators loaded with shredded municipal solid waste and determined the effects of the exposures to leachate on their properties and functioning as liners. The primary liners in this study were: four admix materials - paving asphalt concrete, hydraulic asphalt concrete, soil asphalt, and soil cement; two asphaltic membranes - bituminous seal and emulsified asphalt on a nonwoven fabric; six flexible membranes based on the following polymers - butyl rubber, chlorinated polyethylene, chlorosulfonated polyethylene, ethylene propylene rubber, low-density polyethylene, and polyvinyl chloride.
In addition, 31 different specimens of membrane liners and 9 miscellaneous related materials were buried in the simulators and tested. The scope of the project was further expanded by the immersion testing of 28 polymeric membranes for up to 31 months at ambient temperature, testing of 14 thermoplastic sheetings for up to 40 weeks in a newly developed pouch test, and testing of the water absorption of 11 membranes for 43 weeks at room temperature and 70°C.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Liners, Linings, Leaching, Refuse disposal, Pollution, Decomposition reactions, Plastics	Solid waste management	

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TABLE III

PROPERTIES OF ADMIX LINERS MOUNTED AS BARRIERS

units?

	Asphalt Concrete	Hydraulic Asphalt Concrete	Soil Cement	Soil Asphalt	Bituminous Seal	Fabric + Asphalt Emulsion
Installed in Cell No.	7,13	8,14	9,15	10,16	11,17	12,18
Composition of Barrier Specimen	7.1 asphalt/ 100 aggregate	9.0 asphalt/ 100 aggregate	95 soil, 5 kaolin clay, 10 Type 5 cement, 8.8 water	7.0 SC-800 liq. asphalt/ 100 aggregate	Catalytically-blown asphalt, 4.7 kg/m² (8.7 lb/yd²)	Asphalt (from emulsion) 4.8 kg/m² (8.9 lb/yd²) on polypropylene non-woven fabric
Particle size distribution, %						
Passing 4.76 mm, (4 mesh)	90.7	89.4	88.9	79.2		
" 2.38 mm, (8 mesh)	61.0	67.1	70.6	55.8		
" 1.19 mm, (16 mesh)	45.1	50.9	53.7	39.9		
" 0.595 mm, (30 mesh)	30.1	33.7	38.8	27.3		
" 0.297 mm, (50 mesh)	19.4	21.5	29.2	18.5		
" 0.149 mm, (100 mesh)	11.2	12.4	20.8	13.4		
" 0.074 mm, (200 mesh)	6.6	7.2	15.0	11.4		
Sand equivalent			27	31		
Liquid limit			17.6	17.0		
Plastic limit			non-plastic	non-plastic		
Plasticity index			non-plastic	non-plastic		
Penetration at 25°C	68	68			43	
Penetration (extracted from barrier)	44	62				
Softening point, °C (°F)					89 (192)	
Penetration index					+5.2	
Viscosity, capillary at 60°C, cS				1101		
Viscosity, sliding plate at 25°C, at 0.05 sec⁻¹, MP	14.5	9.7		0.20	8.5	4.5
Viscosity, sliding plate at 25°C, at 0.001 sec⁻¹, MP	20.0	14.5		0.14	19.3	6.0
Microductility at 25°C, mm	40	76		7	2	29
Thickness of barrier specimen, cm (in.)	5.6 (2.2)	6.1 (2.4)	11.4 (4.5)	10.2 (4)	0.8 (0.3)	0.8 (0.3)
Density, g./cm³ (lb/ft³)	2.387 (149.0)	2.416 (150.8)	2.169 (135.4)(dry)	2.228 (139.1)		
Void ratio (vol. voids/vol. solids), %	6.4	2.9		10.4	0	
Water swell mm (0.001 inch)	0.03 (1)	0	0	0.43(17)		
Coefficient of permeability, cm/sec. (Ref. 21)	1.2×10^{-8}	3.3×10^{-9}	1.5×10^{-6}**	1.7×10^{-3}	$< 10^{-9}$	$< 10^{-9}$
Compressive strength, MPa (lb/in²)	19.34 (2805)	18.70 (2712)	13.17 (1910)	8.40 (1218)		
Compressive strength after 24 hr immersion*	15.38 (2230)	16.05 (2328)	9.12 (1323)	1.27 (184)		
% retained	80	86	69	15		

* Asphalt Cement and Hydraulic Asphalt Cement immersed in water at 60°C, Soil Asphalt and Soil Cement at R.T.

** Measured on molded specimen

APPENDIX A (Continued). PROPERTIES[a] OF UNEXPOSED MEMBRANE LINERS

Polymer		Polyvinyl chloride					PVC+Pitch
Liner number[b]	Direction of test	87	88	89	92A	93	52
Analytical properties							
Specific gravity		1.245	1.255	1.308	...	1.283	1.294
Ash (db), %		5.34	2.80	5.67	5.84	4.94	9.46
Volatiles, %		0.03	0.17	0.03	0.23	0.12	0.39
Extractables (db), %		38.13	33.46	25.17	32.75	32.26	...
Physical properties							
Average thickness, mils		22	20	11	20	11	80
Tensile strength, psi	Machine	3020	3395	3715	2435	3575	1185
	Transverse	2765	2910	3085	2145	3035	1005
Elongation at break, %	Machine	385	325	315	245	325	150
	Transverse	415	335	325	255	350	175
Tensile set, %	Machine	192	102	196	43	98	36
	Transverse	207	101	205	48	117	18
S-100, psi	Machine	1250	1870	1845	1515	1750	1175
	Transverse	1110	1600	1530	1365	1420	860
S-200, psi	Machine	1820	2610	2715	2170	2580	...
	Transverse	1585	2190	2195	1885	2055	...
Tear strength (Die C), ppi	Machine	340	460	410	435	400	290
	Transverse	295	470	390	375	360	210
Puncture resistance							
Stress, lbs		27.8	28.6	17.0	27.4	0.55	62.3
Elongation, in		0.68	0.56	0.48	0.62	15.90	0.49
Thickness, mils		22	...	11	20	...	80
Hardness, Durometer points							
5 sec reading		75A	80A	82A	82A	78A	~69A
Exposure conditions[d]		Su,Im	Su,Im	Im	Su	Su,Po	Im

[a]Analytical properties: specific gravity and ash, ASTM D297; volatiles, percent loss of weight after two hours at 105°C; extractables, Matrecon method (ASTM D3421, modified).
Physical properties: tensile, elongation, modulus, and set, ASTM D412; tear strength, ASTM D624; puncture resistance, FTMS 101B, Method 2065; hardness, ASTM D2240.

[b]Contractor's liner numbers. R = fabric-reinforced.

[c]Elongation at maximum stress.

[d]Exposure conditions:
- PR - Primary
- Su - Secondary
- Im - Immersion
- Po - Pouch test
- CB - Collection bag
- LS - Liner for simulator

APPENDIX B-1. COMPOSITION AND PROPERTIES OF ADMIXED AND ASPHALT MEMBRANE LINERS - UNEXPOSED AND AFTER EXPOSURE

	Asphalt concrete	Hydraulic asphalt concrete	Soil cement	Soil asphalt
Basic composition	7.1 parts 60-70 pen paving asphalt, 100 parts aggregate	9.0 parts 60-70 pen paving asphalt, 100 parts aggregate	95 parts soil, 5 parts Kaolin clay, 10 parts type 5 cement, 8.8 parts water	7.0 parts SC-800 liquid asphalt, 100 parts aggregate
Thickness, in.	2.2	2.4	4.5	4
Tests of aggregates				
Particle size distribution of aggregate				
Passing 4 mesh, %	90.7	89.4	88.9	79.2
" 8 " , %	61.0	67.1	70.8	55.8
" 16 " , %	45.1	50.9	53.7	39.9
" 30 " , %	30.1	33.7	38.8	27.3
" 50 " , %	19.4	21.5	29.2	18.5
" 100 " , %	11.2	12.4	20.8	13.4
" 200 " , %	6.6	7.2	15.0	11.4
Soil tests				
Sand equivalent	...	...	27	31
Liquid limit	...	...	17.6	17.0
Plastic limit	...	...	Non-plastic	Non-plastic
Plasticity index	...	...	Non-plastic	Non-plastic
Asphalt tests				
Penetration at 25°C/100 g/5 sec				
Before mixing	68	68	...	...
Extracted from core	44	62	...	...
Microductility at 25°C, mm	40	76	...	7
Properties of unexposed samples				
Density, g/cm^3	2.387	2.416	2.169 (dry)[a]	2.228
lb/ft^3	149.0	150.8	135.4 (dry)[a]	139.1
Voids ratio (vol. voids/vol. solids), %	6.4	2.9	...	10.4
Water swell, mil	1	0	0	17
Coefficient of permeability, cm sec^{-1}	1.2×10^{-8}	3.3×10^{-9}	1.5×10^{-6}[a]	1.7×10^{-3}
Compressive strength				
Initial, psi	2805	2710	1910[a]	1220
After 24 h immersion in water[b], psi	2230	2330	1320[a]	185
Retention of strength after immersion, %	80	86	69[a]	15

See footnotes at end of table.

APPENDIX B-1 (Continued). COMPOSITION AND PROPERTIES OF ADMIXED AND ASPHALT MEMBRANE LINERS - UNEXPOSED AND AFTER EXPOSURE

	Asphalt concrete	Hydraulic asphalt concrete	Soil cement	Soil asphalt
Basic composition	7.1 parts 60-70 pen paving asphalt, 100 parts per aggregate	9.0 parts 60-70 pen paving asphalt, 100 parts per aggregate	95 parts soil, 5 parts Kaolin clay, 10 parts type 5 cement, 8.8 parts water	7.0 parts SC-800 liquid asphalt, 100 parts aggregate
Properties after 12 months of exposure[c]				
Density, as received, g/cm^3	2.430	2.400	...	2.161
Density, dry, g/cm^3	2.[illegible]	2.309	...	1.973
Voids ratio as received, %	3.2	1.5	...	15.2
Voids ratio, dry, % (number of samples)	4.2 (3)	1.9 (4)	...	26.1 (3)
Water content, g water per 100 g dry solids (number of samples)	1.00 (3)	0.45 (4)	...	9.6 (3)
Water soluble solids extracted, % (number of samples)	0.008 (1)	<0.01 (2)	...	0.14 (3)
Compressive strength, psi	423	349	1188	15
Percent of original	15	13	62	1.2
Coefficient of permeability, cm sec^{-1} (two samples)	7.4×10^{-7} 9.3×10^{-9}	3.5×10^{-9} $<3 \times 10^{-10}$	1.5×10^{-8} (T)[d] 4.0×10^{-7} (B)	1.3×10^{-8} 2.8×10^{-8}
Properties after 56 months of exposure[c]				
Density, as received, g/cm^3	2.542	2.471	...	2.307
Density, dry, g/cm^3	2.417	2.385	...	2.019
Voids ratio, as received, %	4.3	4.6	...	5.0
Voids ratio, dry, % (number of samples)	5.3 (2)	3.6 (2)	...	14.3
Water content, g water per 100 g dry solids	1.06	0.96	...	6.51
Water soluble solids extracted, % (number of samples)	0.016 (2)	0.008 (2)	...	0.10 (2)
Compressive strength, psi (number of samples)	258 (2)	172 (2)	1182 (4)	26 (2)
Percent of original	9	6	62	2
Coefficient of permeability, cm sec^{-1}	$<10^{-7}$	$<10^{-9}$	1.2×10^{-5} (T)[d] 2.7×10^{-5} (B) 4.3×10^{-7} (T) 1.2×10^{-5} (B)	8.6×10^{-8} (T)[d] 2.7×10^{-7} (B)

[a]Measured on specimen molded according to ASTM D 558. Wet density, 2.[illegible]5 g cm^{-3} (146.4 lb ft^{-3}).

[b]Asphalt concrete and hydraulic asphalt concrete immersed in water at 60°C; soil cement and soil asphalt immersed at room temperature.

[c]Measured on 2-inch cores cut from liner specimens.

[d]Data for top (T) and bottom (B) of core are shown.

APPENDIX B-2. PROPERTIES OF ASPHALT IN ADMIX MATERIALS AND MEMBRANES AFTER 12, 43, AND 56 MONTHS OF EXPOSURE TO MSW LANDFILL LEACHATE

Type of asphalt	Paving asphalt concrete: Whole core	Paving asphalt concrete: Top	Paving asphalt concrete: Bottom	Hydraulic asphalt concrete: Whole core	Hydraulic asphalt concrete: Top	Hydraulic asphalt concrete: Bottom	Soil asphalt: Whole core	Soil asphalt: Top	Soil asphalt: Bottom	Bituminous seal	Asphalt on non-woven fabric
	60-70 pen paving grade asphalt			60-70 pen paving grade asphalt			Slow curing liquid asphalt, SC-800 grade			Catalytically blown asphalt	Emulsified asphalt
Viscosity at 25°C in sliding plate viscometer at shear rate of 0.05 sec-1:											
Original, MP	5.1[a]	...	...	2.1[a]	...	...	0.02[b]	...	...	8.5	4.5[b]
After 12 months, MP	8.8	...	...	3.3	...	...	0.04	...	...	10.4	2.9
After 43 months, MP	...	...	...	...	...	...	...	...	...	12.2	3.[illegible]
After 56 months, MP	9.9	9.1	10.7	9.9	4.2	13.5	0.01	0.005	0.012	17.4	3.1
Change from original, MP	+4.8	+4.0	+5.6	+7.8	+2.1	+11.4	-0.01	-0.015	-0.008	+8.9	-1.4
Penetration at 25°C at 100 g/5 sec:											
Original	44[d]	...	...	62[d]	...	...	538[b,e]	...	...	36[e]	46[b,e]
After 12 months[e]	36	...	...	52	...	...	390	...	...	34	55
After 43 months[e]	...	...	...	...	...	...	...	...	...	31	53
After 56 months[e]	34	35	33	39	47	30	844	1020	659	27	53
Change from original	-10	-9	-11	-23	-15	-32	+306	+482	+1[illegible]	-9	+7
Voids ratio (volume voids/volume solids x 100):											
Original	5.4	...	...	2.9	...	...	10.4	...	...	...	...
Wet after 12 months	3.2	...	...	1.5	...	...	15.2	...	...	...	...
Wet after 56 months	4.3	...	...	4.6	...	...	5.0	...	...	...	...
Dry after 12 months	4.2	...	...	1.9	...	...	26.1	...	...	...	...
Dry after 56 months	5.3	...	...	3.6	...	...	14.3	...	...	...	...
Softening point, °C:											
Original	...	...	...	...	...	...	...	...	...	89	...
After 12 months	...	...	...	...	...	...	...	...	...	89	...
After 56 months	...	...	...	...	...	...	...	...	...	101	...

[a]Calculated from penetration data.
[b]Asphalt extracted from unexposed specimens stored 12 months.
[d]Asphalt before mixing was 60 penetration, i.e., ca. 1.7 MP.
[e]Calculated from viscosity data.

APPENDIX I

"Battling Groundwater Pollution"

"Hot Mix Keeps Landfill Sanitary"

"Asphalt For Environmental Liners"

ASPHALT

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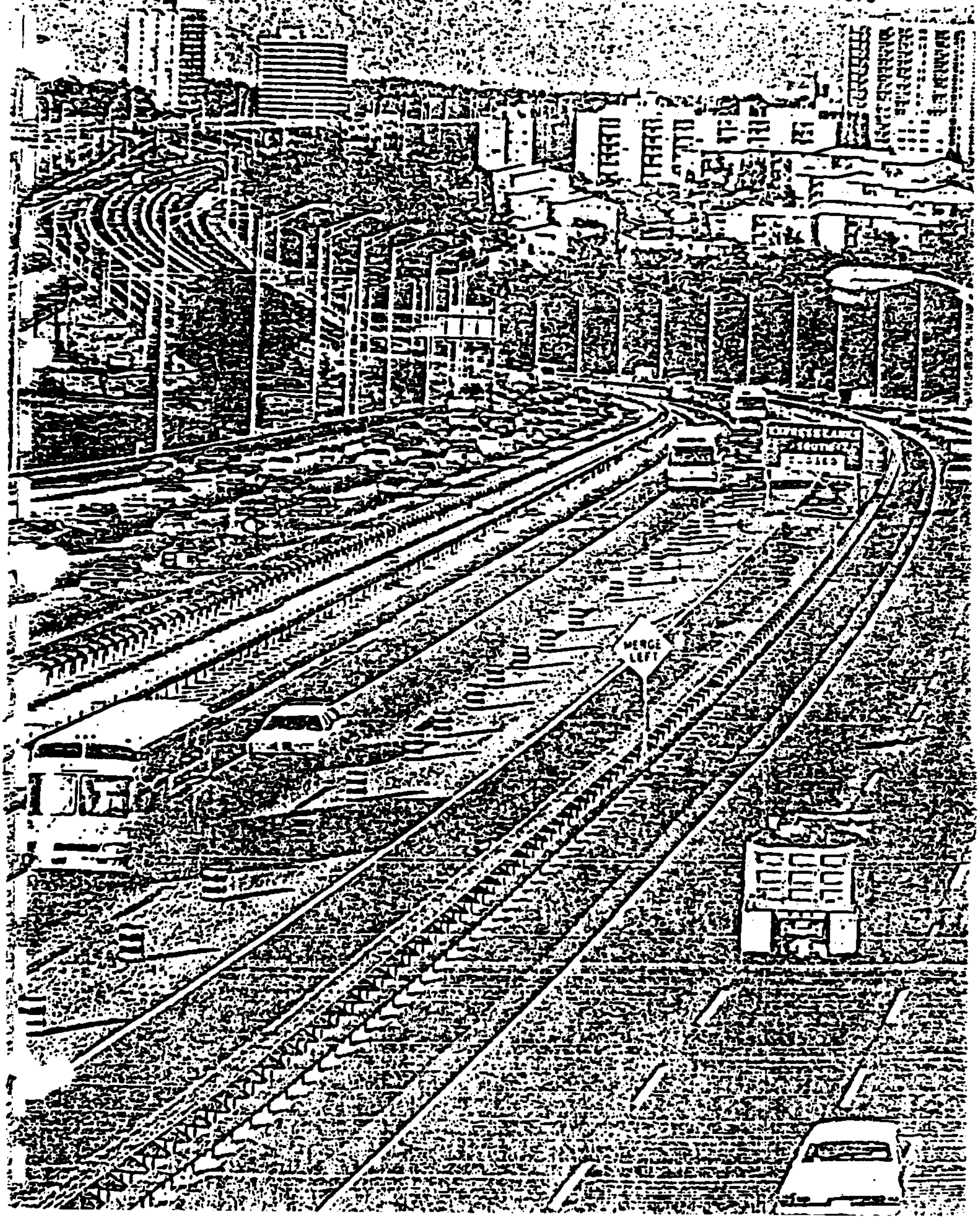
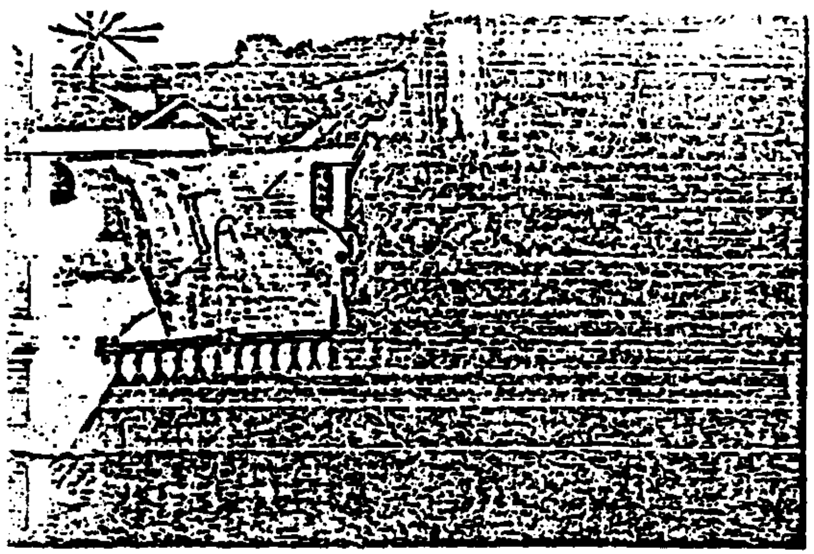




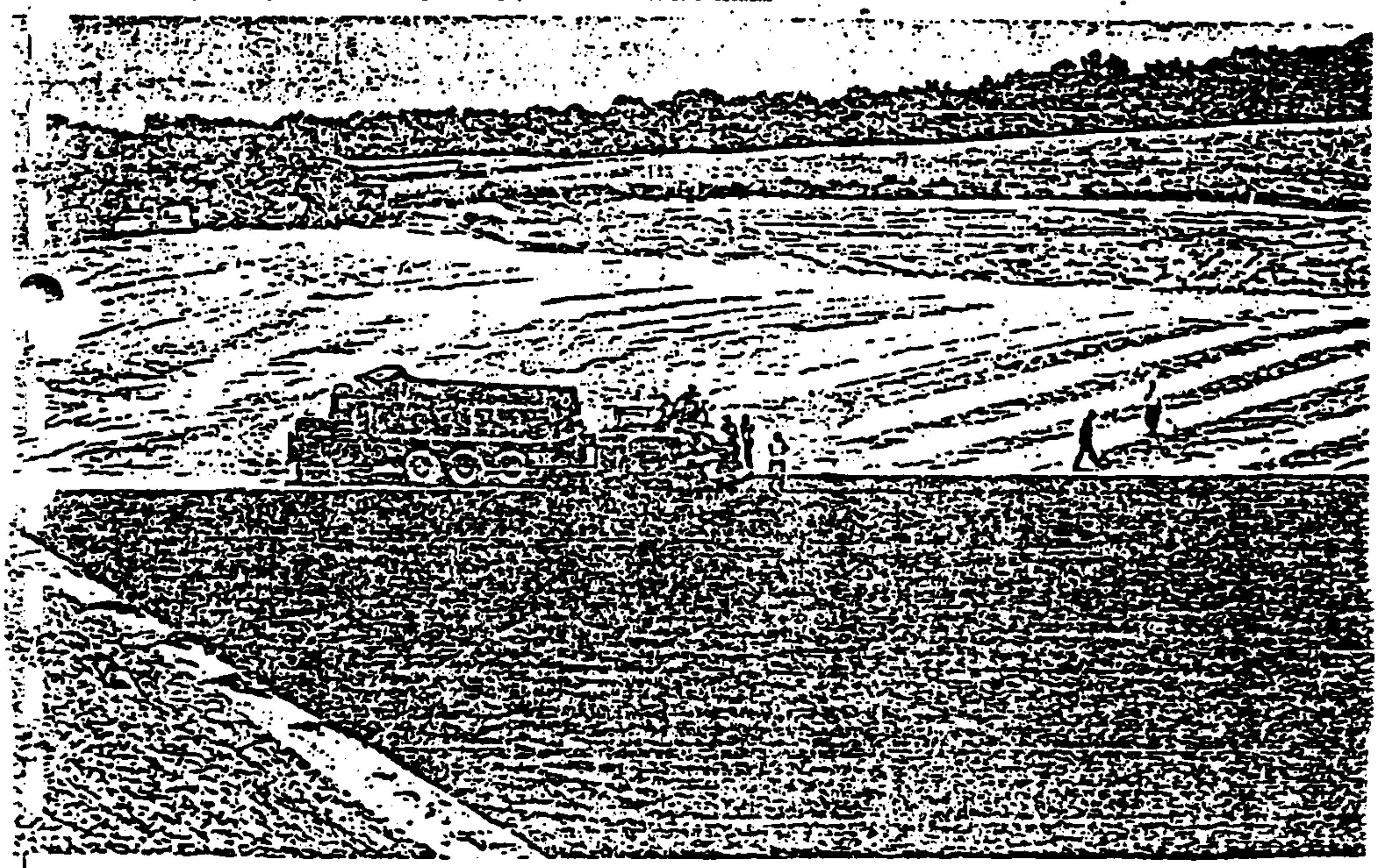
The hot-mix lining is topped with an asphalt cement membrane sprayed in two applications to ensure watertightness. A 12-foot extension bar is being used on the distributor.

The 80-acre Columbia County Sanitary Landfill is being built in stages. A two-inch dense-graded asphalt concrete lining is being placed on a three-acre section.

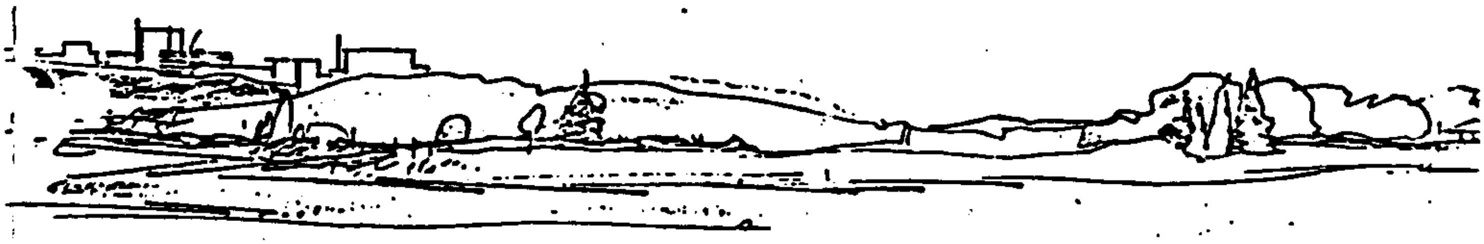
2 HEAD
Excessive
John Rocco
1 x 10^{-12} or 10^{-10}
Standard ASTM

BATTLING GROUNDWATE POLLUTION

By CARL W. LUBOLD, Jr.
District Engineer
The Asphalt Institute



Pa. County Thinks Asphalt-Lined Sanitary Landfill Will Prove Win



Personnel concerned with the sanitary landfill and present during construction, left to right, are: Richard Bittle, Environmental Protection Specialist, Division of Solid Waste Management, Pennsylvania Department of Environmental Resources; Patrick McKenna, Landfill Manager; and David Trenter, Civil Engineer, LeVan, Inc.

(Talked to)

MIX SPECIFICATION AND DESIGN VALUES

$7.25

Specification

Sieve size	% Passing	Design
½"	100	100
⅜"	80-100	93
4	45-80	60
8	30-60	45
16	20-45	32
30	10-35	22
50	5-25	12
100	4-14	8
200	3-10	5
% Asphalt 6.0-8.0		6.8

Marshall Data	
Stability	1850
Flow	11.7
Voids	4.0

Cat 826

John Rosso - 717-787-7381

THE PROBLEM of solid waste disposal is one of the major dilemmas of our clean-air-and-clean-water-conscious society.

Nearly every community faces it. Some cities near the ocean dump garbage and pump raw sewage into the sea. But 90 percent of the solid waste in the United States is disposed of on land. In years past, it was simply transported to an open dump and burned. But not anymore.

Open dumps are being replaced by sanitary landfills in which layers of waste are covered with layers of earth. Afterwards the landfill can be converted into parkland or serve some other useful purpose. Yet, even sanitary landfills can pose a pollution problem. Rainwater draining into contaminated material can carry it down into the groundwater. This leaching process can pollute wells and streams.

The Columbia County Solid Waste Authority in Pennsylvania has overcome this leachate problem by building an asphalt-lined sanitary landfill that meets stringent requirements established by the Pennsylvania Department of Environmental Resources.

The facility, called the Columbia County Sanitary Landfill, is located on a county-owned farm four miles east of the Buckhorn Interchange of Interstate 80 in northeast Pennsylvania. Built in stages, the landfill will eventually grow to 50 acres in size. The first stage, completed last June, consisted of 1.8 acres now nearly filled with waste. A second stage of approximately three acres was paved in July, and a section of about the same size will be built this fall.

From his office in Harrisburg, Mr. Lubold provides Institute engineering service in Pennsylvania. He joined the Institute in 1968 and is a civil engineering graduate of Pennsylvania State University. A specialist in highway engineering and materials, he was previously with the Pennsylvania Highway Department.

Columbia Asphalt Corporation, of Bloomsburg, is paving the second and third sections, bid as one job. The work involves preparation of the subgrade, incorporation of french drains (a trench backfilled with stones) to prevent hydrostatic pressure, paving a two-inch dense-graded asphalt concrete lining, and placing a 0.75 gal/square yard asphalt cement membrane.

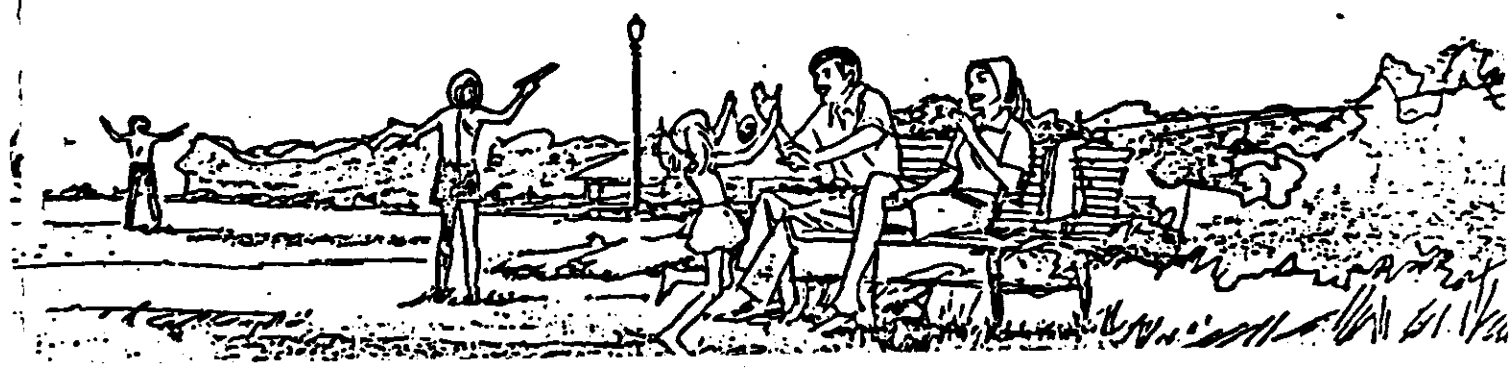
A conventional paver places the hot-mix which is compacted with a vibratory roller. The asphalt cement seal is sprayed in two applications over the paved surface to ensure watertightness. The distributor has a 12-foot extension bar.

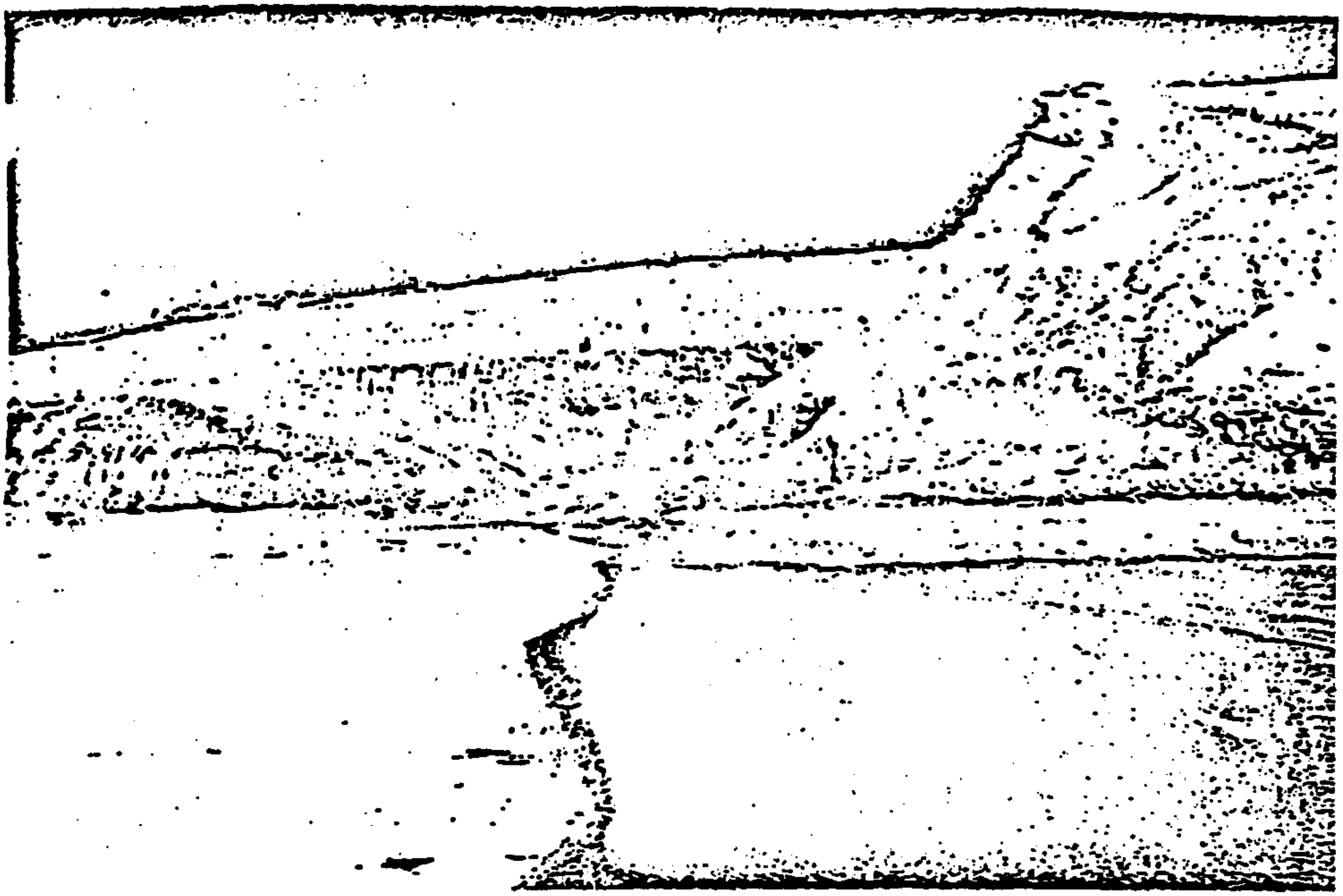
Leachate draining to the asphalt lining is collected by pipes which feed into two large holding tanks. It is then pumped back over the landfill to speed up decomposition. Eventually, leachate will have to be shipped to a sewage treatment plant for further processing.

The consulting engineering firm of LeVan, Inc., of Harrisburg, was engaged to perform a feasibility study and later designed the facility to meet state requirements as set by the legislature.

Projecting the rate of applications made to the Pennsylvania Department of Environmental Resources for sanitary landfill permits, there are indications that upwards of 700 sanitary landfills could be required within the next decade. Assuming a median site size of 100 acres, it is quite possible that ever-increasing volumes of both industrial and municipal refuse will require an additional 70,000 acres of engineered sanitary landfills in Pennsylvania alone during this ten year period.

For an example of how an abandoned gravel pit and rock quarry was converted to a sanitary landfill, see article, "Line It and Put It To Use," in April 1973 issue of Asphalt magazine.





Lanchester Corporation's landfill facility demonstrates the application of the hot-mix asphalt liner. At left (light area) is the prepared subgrade ready for paving. At right is the hot-mix liner with the 14 inches of clean earth atop (near background) and the landfill materials being placed atop it (right rear).

Hot-Mix Keeps Landfills Sanitary

Sanitary landfills are sites for the disposal of waste liquid and solid materials, there to slowly decompose safely and out of .t. One big problem with sanitary .andfills is keeping them sanitary. Precautions must be taken to avoid any contamination from waste materials getting into the surrounding environment, particularly creeks, rivers and ground waters.

The State of Pennsylvania is taking large strides in the development and construction of proper sanitary landfill sites, and one of their quality innovations has been the use of hot-mix asphalt as a landfill liner. Hot-mix is proving to be an ideal barrier material, to keep liquids in or liquids out; in the case of sanitary landfills, it does both.

Hot-mix makes the perfect liner for the landfills because it is easy to put down, follows the contours of the land, is not subject to breakthrough from compacted objects (as many films and fabrics are) and makes a liquid-tight seal. This latter point is especially important in the containing of leachate, a liquid residue which accumulates from the landfill operations is, in many cases, collected and treated before release into waterways or re-used as a wetting-down agent for the landfill.

Another important Pennsylvania development has been the usage of a standard highway wearing course, ID-2 (see table for composition), for the landfill liner paving. Although this mixture is not a "hydraulic" mix and does not meet permeability requirements, this is overcome by treating it with a seal of AC-20 applied at a quantity of 0.6 gallon per square yard in two applications of 0.3 gallon per square yard each.

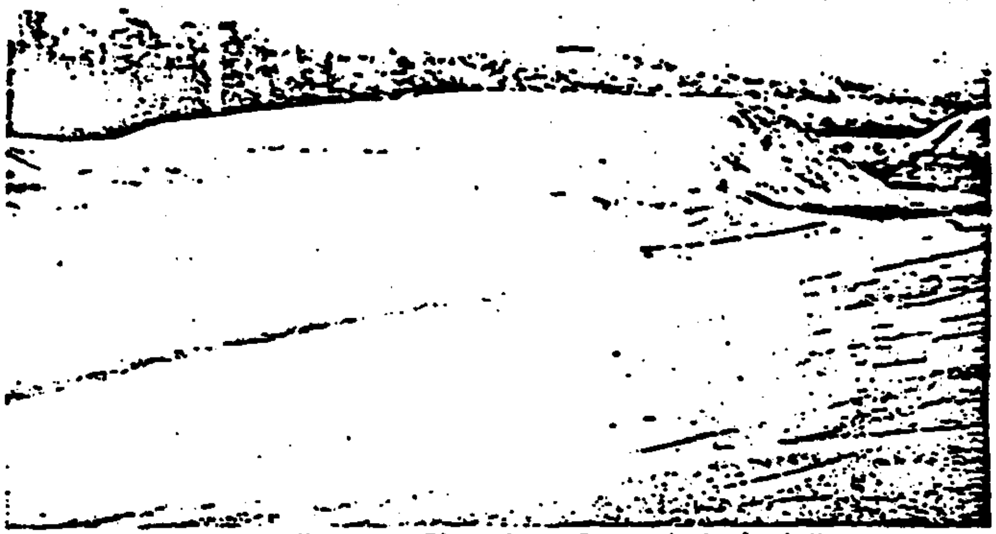
By formulating this mixture around the Pennsylvania Department of Transportation ID-2 specifications, the Pennsylvania Department of Environmental Resources (which has jurisdiction over sanitary landfills) is assured of receiving quality material and workmanship and also led to an economic advantage since contractors are dealing with a familiar mix.

A leader in the concept of quality landfill operations is Lewis R. Frame, owner of the Lanchester Corporation's site near Honey Brook, Pa., (about 40 miles northeast of Philadelphia). The commercial Lanchester operation covers some 525 acres in all and has been in operation approximately 18 months. At expected rate of use (about 2,000 tons of refuse accepted per day), its useful life will be approximately 25 years.

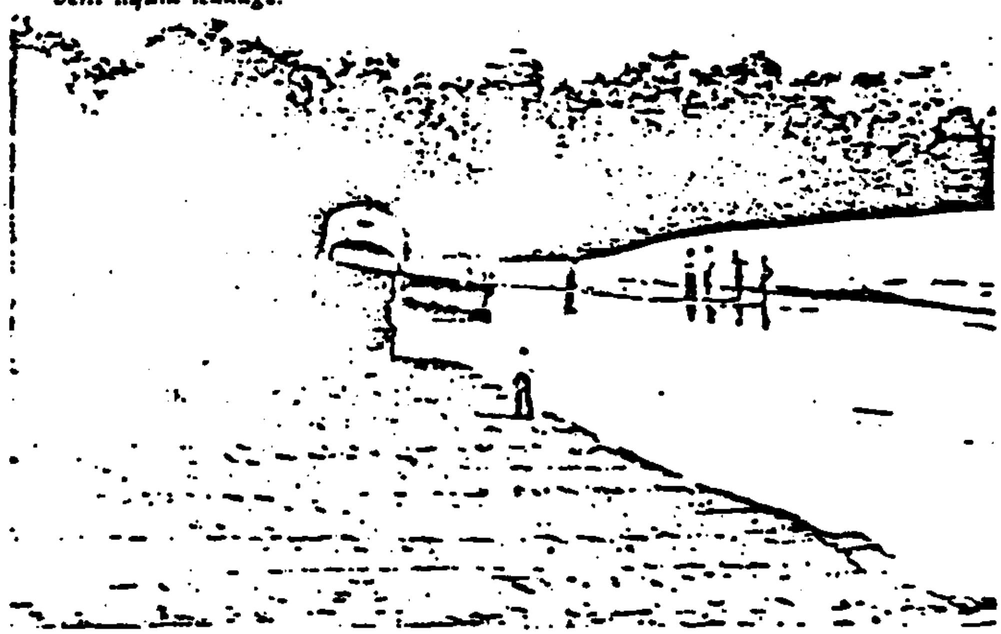
"From the start, I thought the key element in a landfill operation was to do the job right," Lew Frame said. "Since I intend to be in business for a long time, want my facility to be an asset, not a detriment to the community, and also have to meet especially stringent environmental considerations, it was imperative that no corners be cut in our operation. Since this facility will also be handling hazardous materials, it was also essential that quality and care be used throughout." How well he's succeeded in his goals can be seen by the fact that he has received numerous writeups in magazines and newspapers commenting on the quality of his operation, plus received visitations from en-

Pa. — Wearing — ID-2

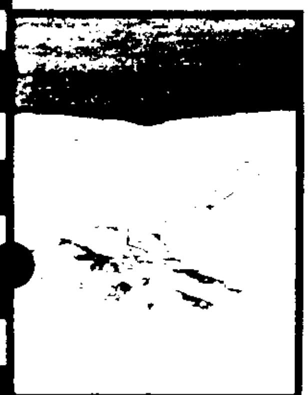
Passing Sieve	Required Composition
1/2"	100
3/8"	80-100
4	45-80
8	30-60
16	20-45
30	10-35
50	5-25
100	4-14
200	3-10
Bitumen, % By Weight	
Stone	4.5-8.0
Slag	7.0-10.5

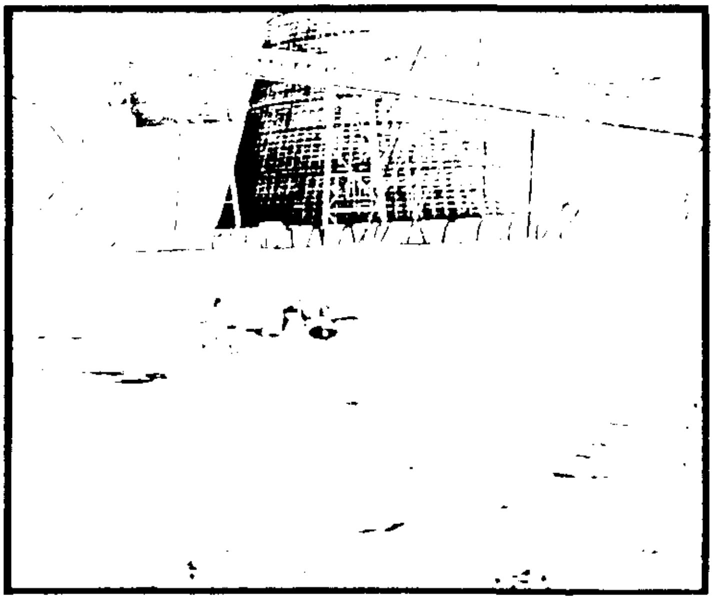


(Above) Paved landfill site near Bloomsburg, Pa., ready for landfill operations to begin. (Below) Sealing the hot-mix liner with a spray application of AC-20 to prevent liquid leakage.



Asphalt for Environmental Liners



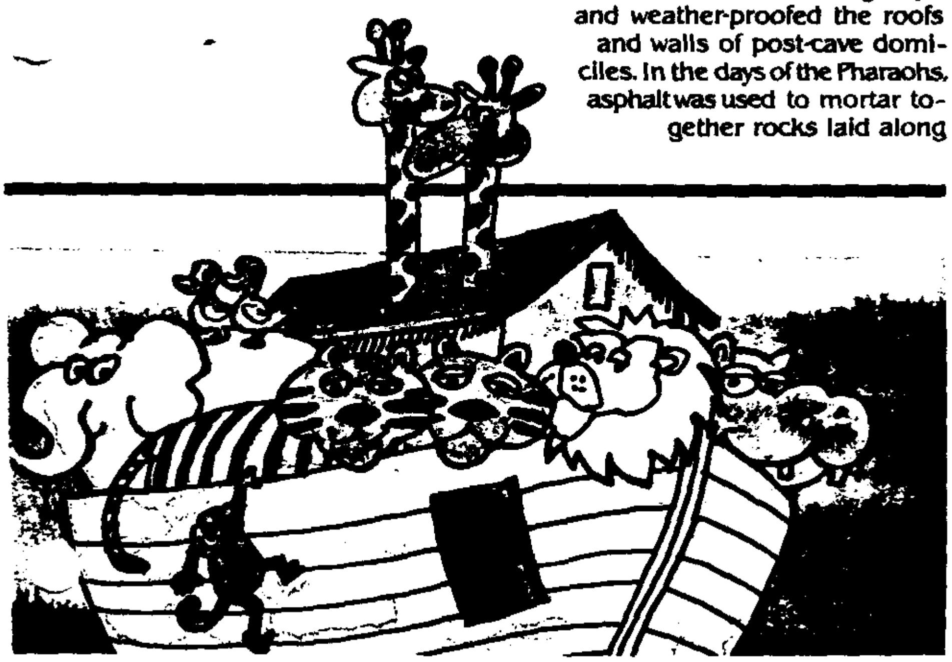


...because whatever you put into a pond, reservoir, lagoon, or landfill you want to keep there!

Asphalt

was used for water-proofing long before it was used for load-bearing.

Thousands of years before. Asphalt, or "pitch" in its natural form, caulked the seams of the world's sailing ships and weather-proofed the roofs and walls of post-cave domiciles. In the days of the Pharaohs, asphalt was used to mortar together rocks laid along

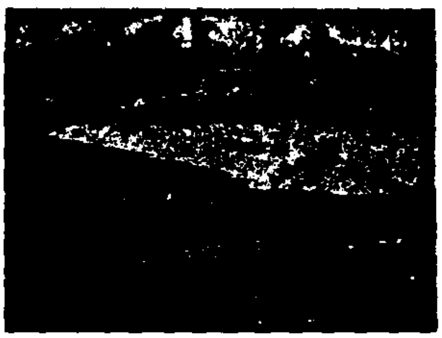


the banks of the Nile to prevent erosion. Even earlier, it was used by civilizations of Mesopotamia and the Indus Valley to water-proof temple baths and water tanks. Notorious for plagiarism, the Romans borrowed the idea for their own baths, reservoirs and aqueducts.

It wasn't until comparatively recently that John MacAdam engineered modern road design and "paved the way" for the use of asphalt in its familiar load-bearing form.

Today, asphalt is again finding favor as a material for storing and processing all kinds of materials because it offers both essential properties—water-proofing and load-bearing.

Hot Mix Asphalt liners take on the toughest jobs—keeping sanitary landfills sanitary; storing toxic materials and preventing their escape into the surrounding environment; making it possible to treat and even recycle liquids and solid wastes; and, of course, keeping clean water clean. No other environmental/hydraulic lining material even comes close!

1 

2 

1 Recycling and composting non-toxic waste materials by a natural drying process

2 At Ludington, Michigan, water storage facility, water pumped in during off hours is released to run electricity-generating turbines during peak hours

All things considered, there's only one possible reason to use anything other than asphalt for your containment system.

You can guess this one possible "reason." A Hot Mix liner may cost more initially than natural materials or fabric membrane liners but it is more cost-effective in the long run and certainly the safest-and-surest liner you can use.

Spotting the competition that much of a head start . . . on paper, at least . . . let's see why Hot Mix Asphalt ends up far in front.

LIQUIDS don't penetrate asphalt*

Now, you may question this statement knowing that asphalt pavement on streets, roads, and parking lots especially seem vulnerable to certain liquids. But this vulnerability is only through cracks in the surface caused by oxidation combined with steady traffic. Used as a liner, there is little if any oxidation and, of course, no steady traffic. Furthermore, to virtually eliminate porosity, a higher percentage of asphaltic binder is used and the material more densely compacted. Generally, liner specifications require voids of less than 2.5 percent which is well within installation capabilities.

ASPHALT pavement is puncture-proof

Membranes may do the job well enough, for a while. However, they suffer from a serious drawback—sharp objects may puncture them and constant abrasion may wear holes. Worse yet, you're not likely to become aware of leakage until considerable environmental damage has been done.

A HOT MIX Asphalt liner will outlast anything it contains

There are two dimensions to the matter of staying power. First, your liner has to remain impermeable for as long as you want it to. Clays, for example, tend to break down and lose their leak-proof properties in time. Then you also face the problem of unwanted plant life taking over. Being inert and stable, Hot Mix Asphalt minds its own business.

Second, your liner may be subject to waves or currents, and it's always subject to vertical and lateral pressures. With its compressive strength and flexibility, Hot Mix Asphalt survives these hazards better than any other material. It may scrunch down a bit but it won't crack!

ASPHALT conforms to irregular surfaces

Environmental containment systems are, after all, basins with curves and undulations as well as flat surfaces. Ponds and lagoons, those used for storm water control and perhaps aesthetics, are liable to be deliberately irregular, with bumps and mounds along the bottom and sides, and a free-form shoreline. Here's another way Hot Mix Asphalt excels. It can be installed uniformly over almost any terrain configuration. (As you know, rigid liners have special problems with this!)

ITS load-bearing properties makes asphalt easy to clean

Anyone with experience . . . perhaps sad experience . . . with any kind of long-term containment system realizes it has to be cleaned out periodically. No problem getting equipment in (and out!) over a Hot Mix Asphalt liner. Something else is worth pointing out. Because of extra compaction during installation, the surface of a Hot Mix liner is smoother than usual which makes the actual cleaning process easier.

ASPHALT won't join forces with waste materials*

Asphalt can handle toxic materials normally difficult to store, including sludge, brine, coal slurry, and many acids. This means that whatever you put into your containment system stays there as is rather than chemically altered.

BEING inert, asphalt doesn't taint drinking water

This is a specialized attribute but critical for reservoirs. Nothing generates uproar faster or more vocally than tangy or discolored drinking water! No wonder Hot Mix Asphalt has been lining reservoirs and dams for years.

**Certain petroleum solvents, however, can affect Hot Mix liners and other toxic liquids may affect certain types of aggregates.*

From all this it would seem that Hot Mix Alphalt liners survive everything short of an earthquake which, you can well believe, is no joke in certain locations. Neither are freeze-thaw cycles in northern areas. Both kinds of natural phenomena will destroy any material too fragile or rigid.

Asphalt will survive intact because it's *flexible*, able to absorb shocks and vibrations without losing its essential properties.

One further liner hazard—familiar to any property owner—is WEEDS. Vegetation can destroy a liner faster and more thoroughly than any other enemy. Before installing any liner you should sterilize the underlying ground but even this preventive measure may not be enough. If your liner allows liquids to seep through, vegetation may again take root below and behind. Soon your liner springs leaks—lots of them!—the new growth enlarges the leaks, and, adding insult to injury, clogs the interior of your pond, lagoon, or reservoir.

3

4

5

6

3 Active sewage aeration treatment facility

4 Four coal slurry storage ponds at Mohave Generating Station in Nevada

5 Asphalt lining underway at South Mountain Reservoir in the Phoenix, Arizona, area

6 Sewage treatment lagoon under construction in Union City, Michigan

The EPA decision acknowledges landfill liner experience

Citing more than 300 "problem" landfills, some of them endangering the health of thousands of people, the Environmental Protection Agency (EPA) has banned the use of clay as a primary liner for both sanitary and hazardous waste landfills. EPA's view is that pollutants enter the pore structure of clay and eventually work their way through. Such liners may be water-retardant but hardly water-proof.

If natural materials and fabric membranes don't do the job, is there solid evidence that Hot Mix Asphalt does do the job? EPA thinks so, listing Hot Mix Asphalt as an acceptable liner for sanitary landfills, but let's see what experiences and results prove our contention.

MORE than ten years ago Pennsylvania was lining sanitary landfills with asphalt. Their standards are widely used in other states today.

PENNSYLVANIA was also a leader in developing *"closed loop" treatment systems.* A secondary pond collects leachates *drained from the bottom of the primary pond.* They can be kept and *released from there or sprayed back over new effluents in the primary pond, collected and run through the loop again until ready for release.* Hot Mix Asphalt lines the secondary pond as well since it does require frequent cleaning.

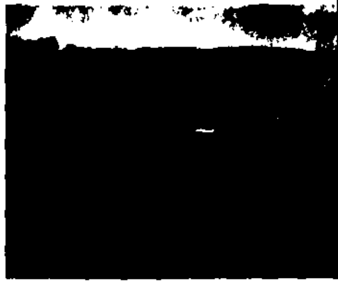
HOT MIX Asphalt replaced concrete years ago in the Ames, Iowa, Solid Waste Resource Recovery System, the first full-scale municipal facility producing refuse-derived fuel for an electric utility. The garbage contained so many jagged edges and abrasives that other liners – proprietary surface mixes, trap rock epoxy, and even metal-impregnated pcc – soon wore through. Finally, and in admitted desperation, they tried an asphalt overlay on one section. It worked so well they resurfaced the entire floor with asphalt and found it lasted two or three times as long as any other material. In the long run, asphalt proved about FIVE TIMES LESS EXPENSIVE than any other liner material.

COAL firms in Kentucky learned that Hot Mix Asphalt makes the ideal base for coal storage piles at terminals. Asphalt contains the coal and provides a load-bearing surface for getting it in and out and also keeps it from absorbing ground moisture.

SPEAKING of storing coal, coal slurry is one of the trickiest of all materials to store and recover of all organic fuels. It's messy and unsightly, and there's always the risk of fire if the coal dries out. The most effective system is a pond where the slurry stands until coal solids settle and excess water can be skimmed off the top. In Nevada, a 20-day coal storage system consists of four ponds about 400 feet across and 40 feet deep. Hot Mix Asphalt, of course, was the only practical liner . . . impermeable and strong.

Sewage aeration lagoon at Westfield, New York, a typical small-community treatment facility

Sanitary landfill showing trench to collect and drain leachate into collection pond.



Hot Mix Asphalt is the answer for those unable to afford complete treatment facilities

Smaller companies and local governments are caught in the ***bind between having to treat waste materials effectively and being unable to afford a tertiary treatment facility and its associated chemicals.***

Many communities have constructed aeration lagoons using asphalt as the liner, as the EPA suggests. **A new approach is aquaculture whereby certain plants are used to reduce nitrogen and phosphorus. Indications are that a one-acre pond just three feet deep and lined with asphalt can treat the effluent generated by 800 people.**

Now, organizations with limited means have an acceptable alternative to expensive treatment plants. They can even recoup some of their investment by harvesting the protein-rich plants – cattails, bullrushes, duckweed, or water hyacinths – and using them for animal feed.

"Ponds make a great amenity but they're a pain in the...!"

Because developers of major residential, industrial, commercial and business projects have to meet local environmental criteria for stormwater management, they naturally think of ponds and the opportunity to combine retention with aesthetics. Any project is enhanced by a pond out front or a landscaped creek winding its way through the property. But nothing is more of a bother! Ponds and creeks have to be maintained and this raised the question as to how and for how much.

The "how" is easy. Hot Mix Asphalt *meets all the design, installation and* maintenance criteria but what about *aesthetics? Asphalt is still ideal. You* can pave just below the surface and *allow a natural shoreline.* Many attractive ponds *are totally lined with as*phalt since it is compatible with natural growth. It even fades obligingly when exposed to sun and air.

Asphalt offers yet another unique feature. It can be blended with different kinds and percentages of aggregate to allow some degree of porosity without loss of integrity. For example, porous asphalt acts as a water-permeable filter which permits some plant penetration without cracking.

The next time you drain your pond for cleaning, why not reline it with Hot Mix Asphalt? *You'll like the "ease of how,"* and your tenants or customers *who share the maintenance burden* will like the lower "how much." *Appearance-wise, everybody will be delighted!*

With its unparalleled combination of strength, durability, flexibility, resistance to hazardous materials, and, of course, impermeability, one might wonder why Hot Mix Asphalt hasn't been used all along to line containment systems. In a way, asphalt is the victim of its own success as the most popular roadway paving material. Its load bearing attributes tend to obscure its original waterproofing attributes.

And, understandably, people ***have been inclined towards what*** **they perceived as less-costly al-*****ternatives. That these alternatives*** **don't work . . . as EPA points out** ***. . . prompts us to take a closer*** **look at Hot Mix Asphalt, to see it's** ***the most cost-effective*** **material for liners.** ***Really the only material now.***

Asphalt-lined ponds combine water retention with aesthetics

napa National Asphalt Pavement Association

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APPENDIX J

Hazardous Waste Quantity Calculations Based on Materials not Delivered to Pagel's Which EPA Included in its Estimate; Summary of Alternate HRS Scores

Hazardous Waste Quantity Calculations Based On Materials Not Delivered To Pagel's Which EPA Included In Its Estimate

#1.	75-33 Gale Products	-	1,592 gals 54,080 gals (1040/wk x 52 wks) 55,672 gals
#2.	75-34 Commercial Wire	-	18 55-gal drums (Metal hydroxide sludge) [900 gals] (18 x 50)
#3.	75-35 Belvidere Hardware	-	20,000 gals metal sludge
#4.	75-36 Automatic Electric	-	16,000 gals caustic sludge
#5.	75-37 Automatic Electric	-	18,000 gals acid sludge
#6.	75-80 Midwest Plating	-	16,000 gals plating waste
#7.	75-81 Midwest Plating	-	4,000 gals plating waste
			130,572 gals

40 C.F.R. Pt. 300, App. A, Section 3.4 conversion factor: 1 drum = 50 gals

130,572 gals ÷ 50 = 2611.44 drums

2737 drums (final EPA score sheet)
2611 drums (material not received as calculated above)

126 drums

HRS score for Hazardous Waste Quantity of 2

Appendix J - Summary of Alternate HRS Scores

HRS Work Sheets	EPA 1984	Scoring Based on Facts A*	B*	C*	D*
Ground Water Route					
observed release	45	0	0	0	0
route characteristics					
depth to aquifer of concern	NA	2	2	2	2
net precipitation	NA	2	2	2	2
permeability of unsaturated zone	NA	2	2	2	2
physical state	NA	3	3	3	3
route score	NA	9	9	9	9
containment	NA	0	2	0	2
waste characteristics					
toxicity/persistence	18	18	18	12	12
hazardous waste quantity	6	2	2	2	2
characteristics score	24	20	20	14	14
targets					
ground water use	9	9	9	9	9
distance to nearest well/population served	30	20	20	20	20
target score	39	29	29	29	29
Total Ground Water Score (includes multipliers)	73.47	0	18.21	0	12.75
TOTAL HRS SCORE	42.47	0	10.53	0	7.37

NOTES

*A = best case score for threatened release of arsenic

*B = worst case score for threatened release of arsenic
(substitution of 9 for targets based upon 0 score for distance to nearest well/population served would result in lower worst case score of 3.26)

*C = best case score for threatened release of phenols

*D = worst case score for threatened release of phenols
(substitution of 9 for targets based upon 0 score for distance to nearest well/population served would result in lower worst case score of 2.29)